

AAMC iCollaborative

Problem-Based Learning Discussions for Teaching Fundamentals of Anesthesia

Authors: Solmaz P. Manuel, M.D., Neelesh Anand, M.D., Sophia P. Poorsattar, M.D.

Description:

During the unprecedented COVID-19 pandemic, the AAMC recommended medical schools suspend student clinical rotations and encouraged medical educators to develop alternative educational tools to provide clinical learning for students. To this end, we developed a series of problem-based learning discussions (PBLDs) designed to walk medical students through the perioperative period they would navigate on their third year anesthesiology rotation.

These PBLDs emphasize fundamental anesthesiology concepts for medical students, including: performing focused preoperative history and physical exam, planning for induction of general anesthesia, confirming successful intubation, and trouble-shooting common postoperative concerns. Each PBLD includes learning objectives, a case stem, key discussion questions, and a facilitator notes attachment. The PBLD modules can be used separately or in a series.

The PBLD sessions are intended to take place with one moderator and a small group (4-8) of medical students. Each of the sessions was designed to last approximately 1 hour. The sessions may take place over a virtual conferencing platform or in person. Ideally, participants are provided the outline and learning objectives of each session with enough time beforehand to familiarize themselves with the format and goals. No other preparation is necessary.

Keywords: Anesthesiology, Preoperative assessment, General Anesthesia, Post Anesthesia Care Unit

Attachments:

PBLD - Preoperative Assessment: "What do we need to know before we step into the operating room?"

PBLD - Induction of General Anesthesia with an Endotracheal Tube

PBLD - Management in the Postoperative Care Unit

Problem-Based Learning Discussion

Preoperative Assessment

“What do we need to know before we step into the operating room?”

Sophia Poorsattar, M.D.

Learning objectives

Upon completion of this problem-based learning discussion, participants should be able to:

1. Perform a focused preoperative history.
2. Identify risk factors for anesthesia.
3. Discuss preoperative cardiac evaluation and how to determine functional status.
4. Perform a focused preoperative physical exam, including airway assessment.
5. Discuss preoperative fasting guidelines.
6. Discuss how the preoperative assessment influences perioperative planning.

Case stem

A 67-year old male, 5' 7" (170.1cm), 98kg (216 lb), BMI 33.8 is scheduled for a right total knee arthroplasty at the ambulatory surgical center. Due to his osteoarthritis, he has had a gradual decline in his ability to ambulate and was subsequently referred for operative repair. His remaining medical history is significant for insulin-dependent diabetes, hypertension, and smoking cigarettes. His medications include metformin, glargine insulin, metoprolol, and lisinopril. His prior surgeries include a tonsillectomy and inguinal hernia repair. Vital signs: BP 158/75, HR 66, RR 14, SpO2 97%, T 36.5C.

Problem-Based Learning Discussion

Preoperative Assessment

“What do we need to know before we step into the operating room?”

Sophia Poorsattar, M.D.

Key Questions

1. You have been asked to see this patient at the Preoperative Anesthesia Clinic one week before the planned procedure. Before you walk into the room, what are your goals for this encounter?
2. You walk into the exam room and introduce yourself. You take a seat and prepare to start your interview. Discuss the elements of the preoperative evaluation.
3. What approach will you take to investigate the patient’s medical conditions?
4. Which of the patient’s medical conditions have implications for the surgery or anesthesia? What will you ask about with regards to these conditions and the implications for each?

You learn that your patient has well-controlled hypertension and diabetes, and he takes his medications regularly. He used to smoke in his 20s, however has not smoked since. He denies all review of systems questioning, including presence of chest pain, palpitations, lightheadedness, shortness of breath, early satiety, gastroesophageal reflux, or leg swelling.

5. What is functional capacity? Why does it matter? How do you determine what your patient’s functional capacity is?

This patient states he lives in a two-story home and is able to climb his stairs multiple times per day without chest pain, dyspnea, or lightheadedness. Despite recent limitations related to knee pain, he continues to perform light weight-lifting at the gym three to four times per week.

6. Does this patient require additional cardiac testing before surgery?
7. Prior to moving on to the exam, briefly review what other questions are important to ask.

8. Moving on to your physical exam, describe how you will conduct an airway assessment. What is Mallampati Class?

Airway exam reveals Mallampati class II, normal thyromental distance, ability to protrude his mandible beyond his maxilla, several missing though no loose teeth, and mildly reduced cervical range of motion. The remainder of the physical exam is unremarkable with the patient appearing awake, alert and neurologically intact, regular rate and rhythm on auscultation of the heart, clear breath sounds bilaterally on auscultation of the lungs, and absence of lower extremity edema or skin changes.

9. Describe the American Society of Anesthesiologists physical status classification system. What is ASA class? What ASA class is this patient?

The patient states that he was told by a friend that he could drink black coffee the morning of surgery, but he wanted to confirm with you that that was correct before doing so.

10. What is preoperative fasting? What will you advise the patient?

Problem-Based Learning Discussion

Preoperative Assessment

“What do we need to know before we step into the operating room?”

Sophia Poorsattar, M.D.

Facilitator Guide

1. You have been asked to see this patient at the Preoperative Anesthesia Clinic one week before the planned procedure. Before you walk into the room, what are your goals for this encounter?

An effective preoperative evaluation should:

- Assess the patient’s overall medical status and ability to tolerate anesthesia for the planned procedure
- Identify if further medical optimization is required prior to surgery
- Identify patient-specific and procedure-specific considerations that may influence the anesthetic plan
- Create a plan for anesthesia and postoperative care
- Obtain informed consent and educate the patient about expectations surrounding the anesthetic care

These goals are important as adequate preoperative patient evaluation, preparation, and communication have been found to improve patient satisfaction and decrease patient complications, delays, cancellations, costs, and mortality. [1]

2. You walk into the exam room and introduce yourself. You take a seat and prepare to start your interview. Discuss the elements of a preoperative evaluation.

The American Society of Anesthesiologists (ASA) Practice Advisory for Preanesthesia Evaluation states that, at a minimum, the preanesthesia evaluation should include:

- Patient interview
- Focused exam of the airway, lungs, and heart
- Review of pertinent medical records
- Indicated preoperative tests
- Consultations with specialists if necessary [2]

3. What approach will you take to investigate the patient's medical conditions?

It is helpful to combine a systems-based and problems-based approach to ensure that you've addressed all known and potential medical problems. Starting with the systems-based approach, focus on major organ systems that are affected during anesthesia: neurological, cardiovascular, pulmonary, gastrointestinal, genitourinary, endocrine and metabolic, hematologic, and musculoskeletal. Next, for each system that you review, include specifics about the patient's known medical problems. For example, while discussing cardiovascular history, ask about history and management of the patient's hypertension.

4. Which of the patient's medical conditions have implications for the surgery or anesthesia? What will you ask about with regards to these conditions and the implications for each?

This patient has a history of obesity, diabetes, hypertension, and tobacco use. Each of these diseases matter because they are systemic diseases that affect every organ system in the body and they are going to change how you treat this patient perioperatively. Investigation will reveal if it is necessary or possible to improve the patient's health condition prior to surgery or if further testing is needed to reduce perioperative morbidity and mortality. Below is a brief list of considerations for each of this patient's comorbidities. *This is not meant to be comprehensive, but rather to facilitate discussion.*

Obesity: Multi-systemic concerns include: cerebrovascular accidents, sedentary lifestyle, reduced exertional capacity, hypertension, coronary artery disease, peripheral vascular disease, obstructive sleep apnea, obesity hypoventilation syndrome, rapid desaturation with apnea (decreased functional residual capacity, increased closing capacity), difficulty with respiratory mechanics (decreased compliance), postoperative apnea, poor glucose tolerance, altered drug effects, osteoarthritis, difficult airway, difficult venous access, difficult monitoring, and difficult positioning. [3]

Diabetes: Multi-systemic concerns include: cerebrovascular accidents, hypertension, coronary artery disease, dysautonomia, stiff joints with limited cervical mobility, hypoglycemia (neurological injury), hyperglycemia (diabetic ketoacidosis, hyperosmolar hyperglycemic syndrome), renal insufficiency, bladder dysfunction, gastroparesis, hypercoagulability, increased risk of infection, and poor wound healing. [4]

Hypertension: Multi-systemic concerns include: cerebrovascular accidents, altered cerebral autoregulation curve, coronary artery disease, congestive heart failure, peripheral vascular disease, renal insufficiency.[5]

Inhaled tobacco use: Multi-systemic concerns include: cerebrovascular accidents, subarachnoid hemorrhage, coronary artery disease, coronary vasospasm, peripheral vascular disease, thromboembolic disease, poor oxygen supply/demand balance (decreased supply from elevated carboxyhemoglobin levels and chronic hypoxemia, increased consumption from nicotinic activation of the autonomic nervous system), chronic obstructive pulmonary disease, increased airway reactivity, sputum production, frequent pulmonary infections, VQ mismatch (resulting in hypoxemia and hypercarbia), and bullous disease. [6]

What you quickly notice is that while it may be easy to disregard these very common comorbidities, without proper consideration and inquiry, serious associations may be missed and the patient's already elevated risk for perioperative complications may be further elevated.

You learn that your patient has well-controlled hypertension and diabetes, and he takes his medications regularly. He used to smoke in his 20s, however has not smoked since. He denies all review of systems questioning, including presence of chest pain, palpitations, lightheadedness, shortness of breath, early satiety, gastroesophageal reflux, or leg swelling.

5. What is functional capacity? Why does it matter? How do you determine what your patient's functional capacity is?

Functional capacity assesses a person's cardiopulmonary fitness and is used as a predictor for perioperative risk. Metabolic equivalents (METs) express the amount of energy expended during one minute of activity. 1 MET is the amount of energy expended during 1 minute at rest and is equivalent to approximately 3.5 mL O₂/kg/min. 10 METs is the amount of energy expended during highly vigorous activity and is equivalent to approximately 35 mL O₂/kg/min. For practicality, functional capacity assessment can be grouped into three categories: poor (<4 METs), moderate (4-7 METs), and excellent (>7 METs).

A common way to question patients regarding their functional capacity is to ask what their most strenuous exercise is that they perform regularly, and if during that exercise they experience any symptoms suggestive of end organ oxygen supply/demand mismatch, such as chest pain, dyspnea, or

lightheadedness. If they experience any of those symptoms, their functional capacity would be the MET below that. Below is a table with assigned MET values for many common activities. [7]

MET	Functional Levels of Exercise
1	Eating, working at computer, dressing
2	Walking down stairs, cooking
3	Walking 1-2 blocks
4	Raking leaves, gardening
5	Climbing 1-2 flights of stairs, dancing, bicycling
6	Playing golf, carrying clubs
7	Playing singles tennis
8	Rapidly climbing stairs, jogging slowly
9	Jumping rope slowly, moderate cycling
10	Swimming quickly, running or jogging briskly

The inability to climb two flights of stairs or walk four blocks on flat ground (METs <4) is predictive of an increase in postoperative cardiopulmonary complications after non-cardiac surgery. Using clinical predictors and functional status, the American College of Cardiology/American Heart Association (ACC/AHA) established guidelines for cardiovascular evaluation for noncardiac surgery. In their guidelines, they describe an algorithm for determining whether a patient is of appropriate risk to proceed with surgery or whether a patient requires further cardiac testing prior to proceeding with surgery. [8]

This patient states he lives in a two-story home and is able to climb his stairs multiple times per day without chest pain, dyspnea, or lightheadedness. Despite recent limitations related to knee pain, he continues to perform light weight-lifting at the gym 3-4 times per week.

6. Does this patient require additional cardiac testing before surgery?

Using the ACC/AHA algorithm: Despite our patient having known risk factors for coronary artery disease, given that he has no active cardiac conditions, is presenting for low risk surgery, and has adequate functional capacity (≥ 4 METs), he is at an acceptable risk to proceed with surgery without further cardiac testing. [8]

7. Prior to moving on to the exam, briefly review what other questions are important to ask.

In addition to reviewing the patient's medical history, it is important to review the following:

- Medications (including what they are being taken for, what their dosing and schedule is, and when they were last taken)
- Allergies (including their reaction and what alternatives have worked in the past)
- Prior operations (including history of complications from anesthesia, difficult airway, severe postoperative nausea and vomiting, or malignant hyperthermia)
- Relevant social history (including the use of tobacco, alcohol, or illicit drugs)

8. Moving on to your physical exam, describe how you will conduct an airway assessment.

What is Mallampati Class?

The purpose of an airway assessment is to determine what risk factors the patient may have for difficult mask ventilation and/or difficult intubation. Identifying risk factors in the history and physical exam will allow you to prepare accordingly and determine what technique, equipment, and possible additional personnel may be needing for airway management.

One component of the airway exam is the Mallampati Airway Classification. This grading system was originally established to predict difficult intubation. Visible oral anatomy is assessed by asking your seated patient to maximally protrude their tongue while maintaining their head in a neutral position. A Mallampati grade is assigned by judging the size of the protruded tongue relative to the oral cavity, and the space remaining for laryngoscopy.

Modified Mallampati Class	Visible Anatomy
Class I	Complete visualization of the soft palate, uvula, fauces, and tonsillar pillars
Class II	Visualization of the soft palate, and only the base of the uvula
Class III	Visualization of only the soft palate
Class IV	Visualization of only the hard palate

Components of the airway exam include:

- Mallampati class*+
- Length of upper incisors
- Condition of teeth*
- Relationship of upper (maxillary) to lower (mandibular incisors) incisors
- Ability to protrude lower incisors in front of upper incisors*+
- Inter-incisor distance+
- Tongue size
- Presence of heavy facial hair*
- Compliance of mandibular space
- Thyromental distance with maximal extension*+
- Length of neck
- Thickness or circumference of neck+
- Range of motion of the head and neck+

In addition to physical exam, several risk factors for difficult airway can be determined from the history.

These include:

- Male gender*
- Age > 55 years*
- Body mass index >26 or 30 kg/m²*
- History of snoring or obstructive sleep apnea*
- History of difficult airway+

- History of complications with intubation (e.g., aspiration pneumonia, dental or oral trauma, significant sore throat)
- History of head and neck pathology (e.g., irradiation, surgery, tumors, infections, hematoma, trauma)
- Cervical spine disease or surgery
- Other diseases with associated airway pathology (e.g., acromegaly, rheumatoid arthritis, ankylosing spondylitis, Marfan's syndrome, Pierre-Robin syndrome, Klippel-Feil abnormalities of the cervical spine, spinal muscular atrophy)

*Predictors for difficult mask ventilation, defined as inability of an unassisted anesthesiologist to maintain adequate oxygenation or reverse sign of inadequate ventilation.

+Predictors for difficult intubation, defined as inability to visualize the vocal cords during laryngoscopy.

[9,10]

Airway exam reveals Mallampati class II, normal thyromental distance, ability to protrude his mandible beyond his maxilla, several missing though no loose teeth, and mildly reduced cervical range of motion. The remainder of the physical exam is unremarkable with the patient appearing awake, alert and neurologically intact, regular rate and rhythm on auscultation of the heart, clear breath sounds bilaterally on auscultation of the lungs, and absence of lower extremity edema or skin changes.

9. Describe the American Society of Anesthesiologists (ASA) physical status classification system. What is ASA class? What ASA class is this patient?

ASA classification is used to define the patient's relative risk prior to undergoing conscious sedation and general anesthesia. Unique to other risk stratification tools, ASA classification is widely used and reproducible, is not restricted to specific disease processes or surgical procedures, and has been shown to be strongly associated with perioperative risk. There are six classes and one modifier as follows: [1]

ASA Class	Description
Class 1	Normal healthy patient
Class 2	Patient with mild systemic disease and no functional limitation (e.g., mild asthma or well-controlled hypertension. No significant impact on daily activity. Unlikely impact on anesthesia and surgery.)
Class 3	Patient with severe systemic disease with some functional limitation (e.g., renal failure on dialysis or class 2 congestive heart failure. Significant impact on daily activity. Likely impact on anesthesia and surgery.)
Class 4	Patient with severe systemic disease that is a constant threat to life with functional incapacity (e.g., acute myocardial infarction, respiratory failure requiring mechanical ventilation. Serious limitation of daily activity. Major impact on anesthesia and surgery.)
Class 5	Moribund patient who is likely to die in the next 24 hours with or without surgery
Class 6	Brain-dead patient whose organs are being removed for donor purposes
E	If the procedure is an emergency, the physical status is follow by “E” (e.g., 5E)

This patient would be classified as ASA 2. He has several systemic disease processes, though all are well-controlled and without significant impact on daily activity.

The patient states that he was told by a friend that he could drink black coffee the morning of surgery, but he wanted to confirm with you that that was correct before doing so.

10. What is preoperative fasting? What will you advise the patient?

Preoperative fasting is the period of time before a procedure or surgery during which a patient should not have oral intake of either liquids or solids. The goal is to minimize the risk of pulmonary aspiration and its associated complications during the perioperative period.

Due to food materials having differing gastric emptying times, the preoperative fasting period differs according to ingested material. The ASA has published general practice guidelines, however, patient-specific considerations must also be made (e.g., patients with delayed gastric emptying). In healthy patients who are undergoing elective procedures, the recommendations are as follows: [11]

Minimum Fasting Period	Ingested Material
2 hours	Clear liquids (e.g., water, fruit juice without pulp, carbonated beverages, clear tea, black coffee)
4 hours	Human breast milk
6 hours	Infant formula, nonhuman milk, light meal (e.g., plain toast and clear liquids)
8 hours	Fried foods, fatty foods, or meat

For this patient, it is reasonable to recommend the fasting guidelines as stated above. However, also take into account that, while his comorbidities are well controlled, this patient may have delayed gastric emptying related to his obesity and diabetes, and therefore be a higher risk for regurgitation and aspiration.

Problem-Based Learning Discussion

Preoperative Assessment

“What do we need to know before we step into the operating room?”

Sophia Poorsattar, M.D.

References

1. Zambouri A. Preoperative evaluation and preparation for anesthesia and surgery. *Hippokratia*. 2007;1:13–21.
2. Apfelbaum JL, Connis RT, Nickinovich DG, et al. Practice advisory for preanesthesia evaluation: an updated report by the American Society of Anesthesiologists Task Force on Preanesthesia evaluation. *Anesthesiology*. 2012;116:522–538.
3. Adams JP, Murphy PG. Obesity in anaesthesia and intensive care. *Br J Anaesth*. 2000;85:91-108.
4. Robertshaw HJ, Hall GM. Diabetes mellitus: anaesthetic management. *Anaesthesia*. 2006;61:1187-1190.
5. Fleisher LA. Preoperative evaluation of the patient with hypertension. *JAMA*. 2002;287:2043-2046.
6. Licker M, Schweizer A, Ellenberger C, et al. Perioperative medical management of patients with COPD. *Int J Chron Obstruct Pulmon Dis*. 2007;2:493-515.
7. Jette M, Sidney K, Blumchen G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clin Cardiol* 1990;13:555-565.
8. Fleisher LA, Fleischmann KE, Auerbach DA, et al. 2014 ACC/AHA Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery. *J Am Coll Cardiol*. 2014;22:77-137.
9. Miller RD. “Airway Management in the Adult.” *Miller's Anesthesia*. 8th ed. Philadelphia, PA: Churchill Livingstone/Elsevier, 2015.

10. Shiga T, Wajima Z, Inoue T, et al. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. *Anesthesiology*. 2005;103(2):429-37

11. American Society of Anesthesiologists: Practice guidelines for preoperative fasting and the use of pharmacologic agents to reduce the risk of pulmonary aspiration: An updated report. *Anesthesiol* 2017; 126:376–93.

Problem-Based Learning Discussion
Induction of General Anesthesia with an Endotracheal Tube
Neelesh Anand, M.D.

Learning Objectives

Upon completion of this problem-based learning discussion, participants should be able to:

1. Describe the ASA standards for basic anesthetic monitoring.
2. Explain how to perform a rapid sequence induction and explain how it is different from a standard induction of general anesthesia.
3. Understand common medications utilized in induction of general anesthesia, including IV anesthetic medications and neuromuscular blockade medications.
4. List at least three ways to confirm proper endotracheal tube placement.

Case Stem

A 32-year-old male is brought to the operating room for a laparoscopic appendectomy. He has a history significant for uncontrolled GERD but is otherwise healthy. His surgical history is significant for left ACL repair 2 years ago with no complications. The patient has no known allergies. He has no family history of anesthesia complications. He has been NPO for over 8 hours. A full review of symptoms performed preoperatively is negative with the exception of chronic GERD symptoms and abdominal pain consistent with appendicitis. Airway exam is significant for a Mallampati score of 1, thyromental distance of 3 cm, full neck ROM, and normal dentition. The remainder of the physical exam (neuro, cardiac, pulmonary) is unremarkable. His IV access is a 20g IV in the right hand.

Problem-Based Learning Discussion
Induction of General Anesthesia with an Endotracheal Tube
Neelesh Anand, M.D.

Key Questions

1. The patient is brought to the operating room and positioned on the table. What monitors should be placed on the patient before inducing general anesthesia?
2. Describe an appropriate pre-induction checklist.
3. What medications should you have ready when inducing general anesthesia with an endotracheal tube?
4. The patient is on the operating room table. You attending asks you to preoxygenate the patient. How do you preoxygenate a patient before general anesthesia and how do you know that they are adequately preoxygenated?
5. Your attending asks whether this patient requires an “RSI”. What does RSI stand for and how does it differ from a routine induction?
6. You perform a rapid sequence intubation with 70mg lidocaine, 150mg propofol, and 100mg rocuronium. Using a Mac 4 blade, you perform a laryngoscopy and get a full view of the entire vocal cords/glottis. Your attending asks you “what grade view do you have?”
7. You perform orotracheal intubation using a 7.5 size cuffed endotracheal tube (ETT) and secure the ETT at 21cm at the teeth using tape. How can you confirm that the ETT is in the correct place?

Problem-Based Learning Discussion
Induction of General Anesthesia with an Endotracheal Tube
Neelesh Anand, M.D.

Facilitator Notes

1. The patient is brought to the operating room and positioned on the table. What monitors should be placed on the patient before inducing general anesthesia?

Anesthesia and the stress of surgery can cause rapid changes in a patient's status, and therefore the American Society of Anesthesiology guidelines mandate that a qualified anesthesia provider be continuously present and monitoring a patient's oxygenation, ventilation, circulation and temperature while anesthesia care is being provided. The following standard monitors should be used in all anesthesia cases: [1]

1. *Oxygenation* – continuous pulse oximetry with variable pitch pulse tone and a low threshold alarm; measurement of oxygen concentration in inspired gas
2. *Ventilation* – continuous capnography which monitors expired carbon dioxide
3. *Circulation* – blood pressure monitoring and EKG
 - a. Blood pressure – can be obtained via a noninvasive blood pressure cuff (measured at least every 5min) or directly using an arterial catheter (called an arterial line).
 - b. Continuous heart rate
 - c. EKG – typically 3 or 5 leads
4. *Temperature* – temperature probe (typically can be placed after induction, either on skin or in esophagus)

2. Describe an appropriate pre-induction checklist.

There are many mnemonics that review pre-induction checklists. Reviewed here is an example checklist using the mnemonic SOAPTIM:

- **S: Suction** (Confirm that the suction is available and turned on in case emesis or airway secretions are encountered during airway manipulation)

- **O: Oxygen** (Confirm the presence of a functioning O₂ source with the patient breathing 100% O₂ via a facemask that is attached to the anesthesia machine)
- **A: Airway Equipment & Alarms** (Ensure all anticipated airway equipment is available)
- **P: Pre-oxygenation & Positioning** (Confirm that expired O₂ > 80% prior to induction and that the patient is positioned optimally for intubation)
- **T: End-Tidal CO₂** (Confirm ETCO₂ on capnography to ensure the presence of ventilation)
- **I: IV** (Confirm that the IV is patent and working well)
- **M: Medications** (Confirm that medications for induction are drawn up and ready)

3. What medications should you have ready when inducing general anesthesia with an endotracheal tube?

There are many different medication combinations which can lead to a safe induction of general anesthesia with an endotracheal tube. Typically, combinations include 1) an intravenous anesthetic to provide adequate sedation to achieve surgical unconsciousness during laryngoscopy and 2) a neuromuscular blocking drug to provide skeletal muscle paralysis for an optimal intubating environment. [2]

Below is a table that lists common intravenous anesthetics:

Medication	IV Dose	MOA	Advantages	Adverse Effects
Propofol	1-2.5 mg/kg	GABA receptor agonist	Rapid onset and offset; antiemetic properties	Dose-dependent hypotension and respiratory depression; pain during injection
Etomidate	0.15-0.3 mg/kg	GABA receptor agonist	Rapid onset and offset; hemodynamic stability with minimal changes in BP, HR or CO; anticonvulsant properties	Pain during injection; postoperative nausea and vomiting
Ketamine	1-2 mg/kg	NMDA receptor	Rapid onset; increases BP, HR	Increases myocardial

		antagonist	and CO; profound analgesic properties; bronchodilation; maintains airway reflexes and respiratory drive	oxygen demand, Can cause hallucinations. Increases ICP and CBF
--	--	------------	---	--

Below is a table that lists common neuromuscular blocking agents:

Medication	Dose	MOA	Advantages	Adverse Effects
Succinylcholine	1-1.5 mg/kg	Binding to nicotinic acetylcholine receptor causing prolonged depolarization	Rapid onset and offset; used in rapid sequence intubation (RSI)	Can cause hyperkalemia (caution for patients with ESRD, burn, stroke, or prolonged bedbound); post-op myalgia; malignant hyperthermia (MH)
Rocuronium	0.6 mg/kg (For RSI: 1.2 mg/kg)	Non-depolarizing acetylcholine receptor blockade	Less contraindications; have reversal reagent (i.e. sugammadex)	Prolonged effect in ESRD, cirrhosis; anaphylaxis
Cisatracurium	0.15-0.2 mg/kg bolus	Acetylcholine receptor blockade	Metabolized by plasma enzyme; can be used in ESRD and cirrhosis	Bradycardia; bronchospasm; hypotension; anaphylaxis

Common Adjuncts:

- Fentanyl – (Dose: 12.5 – 100 mcg IV bolus) a powerful short acting mu-opioid agonist which provides short acting pain relief. Can be helpful for treating the pain and sympathetic stimulation during laryngoscopy

- Lidocaine – (Dose 1 mg/kg) an amide local anesthetic which can prevent the pain on injection with propofol/etomidate and decrease bronchial reactivity with endotracheal intubation.

The induction of general anesthesia may cause hemodynamic swings, sometimes with hypertension and/or tachycardia from stimulation related to laryngoscopy, followed by hypotension once that stimulation is over related to effects of anesthetic medications, which often can decrease blood pressure. For that reason, it is also advised to have vasopressors (including, but not limited to, phenylephrine and ephedrine) available to treat possible hypotension.

4. The patient is on the operating room table. You attending asks you to preoxygenate the patient. How do you preoxygenate a patient before general anesthesia and how do you know that they are adequately preoxygenated?

Preoxygenation is completed with a facemask attached to the breathing circuit from the anesthesia machine delivering 100% FiO₂ to the patient. Typical anesthesia machines can deliver flows of oxygen up to 10L/min. While holding the mask comfortably over the patient's face, covering the mouth and nose, instruct the patient to take deep breaths in and out through their mouth. As they exhale, you should be able to see a CO₂ waveform on the capnography. If you do not see a CO₂ waveform, it often means that you do not have an adequate "seal" between the mask and the patient's face. Without this "seal," you may be entraining air and subsequently failing to deliver 100% FiO₂. As the patient takes repeated deep breaths, you will notice the end-expiratory O₂ increase on the anesthesia machine monitor.

The goal with preoxygenation is to achieve an adequate reserve of O₂ such that when the patient becomes apneic with induction of anesthesia, the onset of arterial desaturation is delayed. This is important during the time of induction, as difficulties with ventilation and intubation may be unpredictable. Several factors are related to an individual's capacity to store O₂ as well as utilize the O₂ that they have stored. However, a normal, healthy adult has the capacity to store approximately 2 liters of O₂ (this is called their functional residual capacity) and utilizes approximately 200 mL/min of O₂ (this is based on a resting consumption of 3.5 mL/kg/min of O₂). If you were able to achieve the maximal fractional end expiratory O₂ level of 100% in this patient, you would be achieving an O₂ reserve of approximately 10 minutes (2 L divided by 200 mL/min). Based on this rationale, preoxygenation is deemed adequate when the fractional end expiratory O₂ level is >80%.

5. Your attending asks whether this patient requires an “RSI”. What does RSI stand for and how does it differ from a routine induction?

RSI stands for “rapid-sequence induction” and it is performed to reduce risk of aspiration of gastric contents for high-risk patients.[3] Patients that fall into this category include those that are not adequately NPO or have a medical condition that increases aspiration risk (e.g., uncontrolled GERD, hiatal hernia, bowel obstruction, active nausea/vomiting, diabetic gastroparesis). Since this patient has a history of GERD with active symptoms, an RSI would be advised.

An RSI includes special attention to:

- Preoxygenation
- Elevation of the head of the bed to 30 degrees to reduce the risk of passive aspiration of gastric fluid
- May consider application of cricoid pressure in which an assistant applies firm pressure over the cricoid cartilage prior to induction. The aim is to collapse the esophagus such that passively regurgitated gastric fluid cannot reach the hypopharynx. However, it may also decrease lower esophageal tone or make airway management more difficult, therefore, it should be abandoned if having difficulty with the airway.
- IV induction with predetermined doses of medication. Higher doses of neuromuscular blocking drugs are used to achieve optimal intubating conditions as fast as possible (typically within 30 seconds)
 - Succinylcholine 1.5mg/kg, rocuronium 1.2mg/kg
- After the induction medications are given, the patient is NOT mask ventilated to avoid filling the stomach with gas and thereby increasing the risk of aspiration of gastric contents.
- Insertion of cuffed endotracheal tube as quickly as possible and ideally before mechanical breaths are administered. Cricoid pressure can be released once the ETT is in the trachea, cuff is inflated, and placement is confirmed.

6. You perform a rapid sequence intubation with 70mg lidocaine, 150mg propofol, and 100mg rocuronium. Using a Mac 4 blade, you perform a laryngoscopy and get a full view of the entire vocal cords/glottis. Your attending asks you “what grade view do you have?”

The attending is referring to the Cormack-Lehane system which classifies views obtained by direct laryngoscopy based on the structures seen. Grade I is a full view of the glottis, grade II is a partial view of the glottis, grade III is a view of the epiglottis, and grade IV is neither a view of the glottis or epiglottis. As described above, with a full view of the vocal cords/glottis, you have a grade I view. [2]

7. You perform orotracheal intubation using a 7.5 size cuffed endotracheal tube (ETT) and secure the ETT at 21cm at the teeth using tape. How can you confirm that the ETT is in the correct place?

There is no single method for confirming ETT placement that is 100% reliable. Therefore confirming accurate placement with multiple methods is considered standard of care. [4]

Methods to confirm ETT placement include:

- Capnography showing presence of ETCO_2 (once the ETT is connected to the circuit and a mechanical breath is given) Waveform capnography has emerged as the gold standard for confirmation of ETT placement, however, colorimetric end-tidal carbon dioxide detection is frequently used to confirm out-of-operating room intubations.
- Auscultation of the chest to ensure bilateral breath sounds. Endobronchial intubations can present with unilateral breath sounds and high peak pressures with ventilation.
- Auscultation over the stomach to ensure lack of gurgling.
- Observation of equal bilateral chest wall rise and fall with mechanical breaths.
- Direct visualization of the ETT within the trachea using a fiberoptic bronchoscope.
- Vapor within the lumen of the ETT with exhalations.
- Chest x-ray confirming the distal tip of the ETT positioned in the mid-trachea.

Problem-Based Learning Discussion
Induction of General Anesthesia with an Endotracheal Tube
Neelesh Anand, M.D.

References

1. Standards for Basic Anesthetic Monitoring. Committee of Origin: Standards and Practice Parameters (Approved by the ASA House of Delegates on October 21, 1986, last amended on October 28, 2015)
<https://www.asahq.org/standards-and-guidelines/standards-for-basic-anesthetic-monitoring>
(Accessed on April 7, 2020).
2. "Airway Management." Morgan & Mikhail's Clinical Anesthesiology, 6e Eds. John F. Butterworth IV, et al. New York, NY: McGraw-Hill, ,
<http://accessmedicine.mhmedical.com.ucsf.idm.oclc.org/content.aspx?bookid=2444§ionid=193559024>.
3. Rhona CF, Sinclair, BMedSci BM BS MRCP, Mark C Luxton, BM BS FRCA, Rapid sequence induction, Continuing Education in Anaesthesia Critical Care & Pain, Volume 5, Issue 2, April 2005, Pages 45–48, <https://doi.org/10.1093/bjaceaccp/mki016>
4. Hagberg CA, Artime CA. (2014) Airway Management in the Adult. In: Miller RD, Eriksson LI, Fleisher LA, Wiener-Kronish JP, Cohen NH, YoungWL, Eds. Miller's Anesthesia, 8th Edition, Churchill-Livingstone Elsevier, Philadelphia, 1647-1683.
<http://dx.doi.org/10.1016/b978-0-443-06959-8.00050-9>

Problem-Based Learning Discussion
Management in the Postoperative Care Unit
Solmaz Manuel, M.D.

Learning Objectives

Upon completion of this problem-based learning discussion, participants should be able to:

1. Develop a differential diagnosis for delayed emergence from anesthesia with understanding of appropriate interventions to narrow the differential and treat reversible causes.
2. Interpret an arterial blood gas in a patient with respiratory depression.
3. Identify patient-related, surgical procedure-related, and anesthetic management-related risk factors that are associated with postoperative respiratory depression.
4. Identify risk factors associated with postoperative nausea and vomiting and formulate a plan to mitigate.
5. Describe the benefits of a multimodal approach to postoperative pain management.

Case Stem

A 75 year old male with past medical history significant for hypertension and obstructive sleep apnea (not requiring CPAP, preop SpO₂ 98% on room air) undergoes laparoscopic cholecystectomy under general anesthesia. The anesthesia team reports that mask ventilation was easy after oral airway assistance and he was intubated in a single attempt with a Macintosh 3 laryngoscope blade and 7.5mm endotracheal tube. He has no known medication allergies, received 2g cefazolin, neuromuscular blockade and reversal with sugammadex, a total of 100mcg fentanyl and 2mg hydromorphone, and 4mg ondansetron. After turning off all anesthetics he remained unconscious without purposeful movements, but breathing without ventilator support for an hour. At that time he became arousable to stimulation and he was uneventfully extubated and transferred to the post anesthesia care unit (PACU).

Problem-Based Learning Discussion
Management in the Postoperative Care Unit
Solmaz Manuel, M.D.

Key Questions

1. What could be the cause of this patient's delayed emergence from anesthesia?

2. After 15 minutes your patient continues to appear somnolent and his pulse oximetry now reports a SpO₂ of 95% on 4L O₂ nasal cannula. His heart rate is 105 bpm and blood pressure 176/84. Which lab tests, if any, would you order? Why?

3. You draw an ABG and find his PaCO₂ to be 70. What is his estimated PaO₂? What is the likely cause of his abnormalities?

4. What are risk factors for respiratory depression in the PACU?

5. What interventions, if any, would you make?

6. The patient's partner asks when he can be discharged home.

7. Thirty minutes later your patient is more awake, but the recovery room nurse tells you he is complaining of nausea. What factors increase risk of postoperative nausea and vomiting?

8. Upon talking to your patient you learn he has a history of motion sickness and is a nonsmoker. What is your management approach to his PONV?

9. Now that your patient is awake, interactive and less nauseous, he would like to know what the plan is to manage his postoperative pain. What strategy do you suggest?

Problem-Based Learning Discussion
Management in the Postoperative Care Unit
Solmaz Manuel, M.D.

Facilitator Notes

1. What could be the cause of this patient's delayed emergence from anesthesia?

Delayed emergence from general anesthesia is defined as a failure to regain consciousness with purposeful movement and intact protective reflexes within 60 minutes after the last administration of any opioid, sedative-hypnotic, or other anesthetic medication.

It is important to have a deliberate method for working through the cause of delayed emergence. Below is one checklist of causes and interventions for delayed emergence:

Potential Causes of Delayed Emergence	Intervention
Hemodynamic or cardiac instability Hypoxia Hypothermia	Evaluate vital signs: blood pressure, oxygen saturation, cardiac rate and rhythm, core body temperature - Supportive care as appropriate
Oxygenation Ventilation	Arterial blood gas, supplemental oxygen and support ventilation as appropriate
Residual neuromuscular blockade	Peripheral nerve stimulation and neuromuscular blockade reversal as appropriate
Residual sedation	External stimulation, Physostigmine (reversal of anticholinergic drugs), Flumazenil (reversal of benzodiazepines)
Opioid overdose	Naloxone titrated to effect
Electrolyte imbalance Metabolic disturbance	Blood chemistry, arterial blood gas, blood glucose measurement

Hypoglycemia	
Stroke Seizure High intracranial pressure	Neurologic examination, CT scan

2. After 15 minutes your patient continues to appear somnolent and his pulse oximetry now reports a SpO₂ of 95% on 4L O₂ nasal cannula. His heart rate is 105 bpm and blood pressure 176/84. Which lab tests, if any, would you order? Why?

With a low SaO₂ we would like more information about what kind of problems he may be having with oxygenation and ventilation. An arterial blood gas (ABG) would give us additional information.

3. You draw an ABG and find his PaCO₂ to be 70. What is his estimated PaO₂? What is the likely cause of his abnormalities?

The familiar oxy-hemoglobin dissociation curve plots SaO₂ versus PaO₂ to tell us that a SaO₂ of 95% is roughly associated with PaO₂ of 80mmHg.

Share with group: The ABG shows pH 7.16, PaCO₂ 70 mmHg, and PaO₂ 79 mmHg on 36% oxygen (4L nasal cannula). This ABG is consistent with an acute respiratory acidosis.

The respiratory acidosis is caused by retention of CO₂, seen as an elevated PaCO₂. A rule of thumb that is often broken in the real world: for an acute respiratory issue, every 10mmHg deviation of PCO₂ from 40mmHg causes an inverse change in pH by 0.08.

In addition, the A-a gradient = PAO₂ - PaO₂

where PAO₂ = (Patm - P_{water})(FiO₂) - PaCO₂/0.8

A-a gradient = [(760 - 47)(0.36) - 70/.8] - PaO₂

= 257 - 88 - PaO₂

= 169 - 79 = 90

If the A-a gradient was normal, it would suggest the low PaO₂ is due to hypoventilation alone. But the elevated A-a gradient suggests his low PaO₂ is caused by hypoventilation plus a diffusion defect, V/Q mismatch, or shunt. Hypoventilation is most likely caused by airway obstruction and respiratory depression in this case. Your patient also probably has some atelectasis/collapsed alveoli after general anesthesia causing shunt as well.

4. What are risk factors for respiratory depression in the PACU?

Respiratory depression with associated ventilation and oxygenation issues are unfortunately very common in the PACU. The most frequent causes are airway obstruction due to loss of pharyngeal muscle tone, residual effects of anesthetic medications, residual neuromuscular blocking drugs, and excessive opioids. Respiratory failure in the PACU can also be due to splinting from pain, diaphragmatic dysfunction, muscular weakness, and depressed respiratory drive. [1]

There are many patient-related, surgical procedure-related, and anesthetic management-related risk factors that have been associated with postoperative respiratory problems.

Patient-related factors: History of chronic obstructive pulmonary disease, asthma, obstructive sleep apnea, obesity, heart failure, pulmonary hypertension, upper respiratory tract infection, smoking, and higher American Society of Anesthesiologists status.

Procedure-related factors: Surgical incision near the diaphragm, upper airway procedures, craniotomies, and procedure duration >3 hours.

Anesthetic-related factors: Duration of general anesthesia, administration of neuromuscular blocking agents, administration of opioids.

5. What interventions, if any, would you make?

Respiratory depression can be fatal if untreated. However, with prompt intervention complications of respiratory depression are avoidable. Hopefully, since the time you were initially called to assess the patient, you have been simultaneously supporting ventilation and oxygenation while also performing your targeted exam, collecting an ABG and possibly ordering a CXR.

Your clinical exam pointed to likely upper airway obstruction. Immediate maneuvers that can be performed to open the upper airway include placing the patient in lateral position or placing a roll behind their shoulders, placing an oral or nasopharyngeal airway, applying jaw thrust, and assisting ventilation with CPAP with bag-mask positive pressure ventilation.

Noninvasive ventilation with CPAP or BiPAP, and endotracheal intubation should be considered if your patient is having continued difficulty with ventilation and oxygenation.

If this patient used CPAP at home, they should have been instructed to bring their CPAP machine with them on the day of surgery to use postoperatively. If they have a CPAP and forgot to bring it, respiratory therapists can help find their appropriate settings on one of the hospital's machines.

6. The patient's partner asks when he can be discharged home.

Due to their propensity to develop airway obstruction or central respiratory depression, the American Society of Anesthesiologists Task Force on Perioperative Management of Patients with Obstructive Sleep Apnea recommends that patients at increased perioperative risk from OSA be monitored for longer than non-OSA patients undergoing similar procedures. Patients must be able to maintain adequate oxygen saturation levels while breathing room air in a nonstimulating environment and preferably while asleep.

[2]

7. Thirty minutes later your patient is more awake, but the recovery room nurse tells you he is complaining of nausea. What factors increase risk of postoperative nausea and vomiting?

Postoperative nausea and vomiting (PONV) is unfortunately seen in approximately 1/3 of surgical patients, and is often rated as one of the most uncomfortable side effects of anesthesia. In addition, PONV is associated with delayed discharge from the PACU, unanticipated hospital admission, and increased incidence of pulmonary aspiration.

Patient risk factors associated with PONV. preoperative nausea and/or vomiting, female gender, history of prior PONV, history of motion sickness, history of chemotherapy-associated nausea and vomiting, NON-smoking status, and younger age in adults.

Anesthetic risk factors associated with PONV: use of volatile anesthetics, use of opioid analgesics, use of nitrous oxide, duration of anesthesia, type of surgery (cholecystectomy, gynecologic, laparoscopic, strabismus, adenotonsillectomy, scrotal or penile procedures). [3]

Apfel et al. developed a simplified Risk Score for PONV (adults): [4]

+1 point for each of the following risk factors:

- Female gender
- Non-smoker
- History of motion sickness or prior PONV
- Expected administration of postoperative opioids

A score of 0, 1, 2, 3, and 4 corresponds to risk of PONV of 9%, 20%, 39%, 60%, and 78% respectively.

8. Upon talking to your patient you learn he has a history of motion sickness and is a nonsmoker. What is your management approach to his PONV?

Management of PONV should ideally include a preoperative assessment of risk factors and administration of multimodal antiemetic medications throughout the perioperative period.

Common pharmacotherapeutics used to prevent and treat PONV include: transdermal scopolamine, aprepitant, dexamethasone, ondansetron, droperidol, haloperidol, metoclopramide, ephedrine, hydroxyzine, and propofol. Additionally, avoiding general anesthesia and opioids by utilizing multimodal analgesics and regional anesthesia techniques will also help reduce PONV.

Patients at high risk for PONV (ie, those with four risk factors according to Apfel's simplified risk score) should receive three or more different interventions. Simply redosing the same antiemetic that was previously ineffective is unlikely to be beneficial.

9. Now that your patient is awake, interactive and less nauseous, he would like to know what the plan is to manage his postoperative pain. What strategy do you suggest?

Given concern for respiratory depression and nausea associated with opioid pharmacotherapy, this patient would benefit from a multimodal pain management plan that optimizes non-opioid pain management tools and uses opioids sparingly.

In recent years perioperative pain management doctors have moved away from old opioid-centred prescribing models, to utilize more from other medication classes. There is convincing evidence that regional anesthesia, nonsteroidal anti-inflammatories, acetaminophen, gabapentinoids, NMDA antagonists, alpha-2-agonists, and local anesthetics (sodium and calcium channel blocking agents) provide effective postoperative pain control. At the same time a multimodal approach decreases opioid side effects and tolerance while also decreasing risk of complications associated with poor postoperative pain control such as pneumonia, deep venous thrombosis, and postoperative cognitive dysfunction. [5]

Problem-Based Learning Discussion
Management in the Postoperative Care Unit
Solmaz Manuel, M.D.

References

1. Nicholau TK. (2014) The Postanesthesia Care Unit. In: Miller RD, Eriksson LI, Fleisher LA, Wiener-Kronish JP, Cohen NH, Young WL, Eds. Miller's Anesthesia, 8th Edition, Churchill-Livingstone Elsevier, Philadelphia, 2924-2945.
<http://dx.doi.org/10.1016/b978-0-443-06959-8.00050-9>
2. Practice Guidelines for the Perioperative Management of Patients with Obstructive Sleep Apnea: An Updated Report by the American Society of Anesthesiologists Task Force on Perioperative Management of Patients with Obstructive Sleep Apnea. *Anesthesiology* 2014;120(2):268-286.
doi: <https://doi.org/10.1097/ALN.0000000000000053>.
3. Apfel CC, Heidrich FM, Jukar-Rao S, Jalota L, Hornuss C, Whelan RP, Zhang K, Cakmakkaya OS. Evidence-based analysis of risk factors for postoperative nausea and vomiting. *Br J Anaesth.* 2012 Nov;109(5):742-53. doi: 10.1093/bja/aes276. Epub 2012 Oct 3. PubMed PMID: 23035051.
4. Apfel CC, Läärä E, Koivuranta M, Greim CA, Roewer N. A Simplified Risk Score for Predicting Postoperative Nausea and Vomiting: Conclusions from Cross-validations between Two Centers. *Anesthesiology* 1999;91(3):693.
5. Wick EC, Grant MC, Wu CL. Postoperative Multimodal Analgesia Pain Management With Nonopioid Analgesics and Techniques: A Review. *JAMA Surg.* 2017 Jul 1;152(7):691-697. doi: 10.1001/jamasurg.2017.0898. Review. PubMed PMID: 28564673.