

DESCRIPTION: General Anesthesiology Elective Curriculum

Whereas the required clerkship is intended to impart knowledge and skills necessary for all physicians, the anesthesiology elective is intended for future anesthesiologists or those physicians for whom acquiring the knowledge and skills utilized by anesthesiologists will be important (i.e. anesthesiology, emergency medicine, critical care medicine, surgery). The student will be expected to perform as an acting intern and participate in all aspects of perioperative care.

Each student will be required to give a brief presentation on a relevant topic, either as part of the Wednesday morning lecture series or in a small group.

The curriculum outlined below is intended as a **study guide**. Its completion is *not required* to achieve a passing grade in the course; grades will continue to be based primarily on clinical evaluations.

(PART 1—PREOPERATIVE EVALUATION)

1. **Perform pre-anesthetic evaluations** by assisting anesthesia residents and attendings in evaluating patients prior to undergoing surgery. The pre-anesthetic evaluation should focus on obtaining a complete medical history and performing a physical exam. General guidelines and relevant information to be obtained as follows:
 - History
 - Confirm planned surgical procedure and reason for undergoing surgery
 - Acute and chronic medical problems
 - Surgical history
 - Anesthetic history-- does the patient have a personal or family history of anesthetic complications, e.g. post-op nausea/vomiting (PONV), allergic reactions, difficult airway or malignant hyperthermia?
 - Allergies to medications
 - Medication reconciliation
 - Pertinent labs, imaging and other diagnostic studies as indicated (stress test, echocardiogram, PFTs, cardiac catheterization, etc.)
 - Physical Exam
 - Focus on HEENT/airway, cardiac, and respiratory systems
 - While performing the airway exam, consider the following:
 - Predictors of difficult mask ventilation
 - Age >55
 - BMI >26
 - Lack of teeth
 - Presence of beard
 - History of snoring
 - Predictors of difficult intubation
 - Mouth opening: incisor distance <3 cm
 - Upper lip bite test: inability to bring lower teeth in front of upper teeth
 - Mallampati classification 3 or 4
 - Thyromental distance < 3 fingerbreadths
 - Neck circumference > 27 in
2. Discuss and participate in the process of **obtaining consent** for anesthesia, including consent for invasive monitoring and/or blood transfusion when appropriate.
3. Discuss the rationale and considerations for **NPO status**, including how they differ for elective versus emergent surgeries.
4. Describe the **ASA physical status** classification.

ASA 1: Normal healthy patient
ASA 2: Patient with mild systemic disease (no functional limitation)
ASA 3: Patient with severe systemic disease (some functional limitation)
ASA 4: Patient with severe systemic disease that is a constant threat to life (functionally incapacitated)
ASA 5: Moribund patient who is not expected to survive the operation
ASA 6: Brain-dead patient whose organs are being removed for donor purposes
E: emergent procedure; may be associated with any of the above numbers

5. Formulate **an anesthetic plan**.
 - Will sedative-hypnotic premedication be useful?
 - Prophylaxis against PONV (post-operative nausea and vomiting)
 - What type(s) of anesthesia will be employed?
 - General
 - Regional
 - Sedation/MAC
 - Are there special intraoperative management issues?
 - Non-standard monitors
 - Positions other than supine
 - Relative or absolute contraindications to specific drugs
 - Fluid management
 - Potential need for blood transfusion
 - How will the patient be managed postoperatively?
 - Management of acute pain
 - Need for mechanical ventilation or hemodynamic monitoring
6. Review the ACC/AHA guidelines for the preoperative evaluation for non-cardiac surgery. (2014 ACC/AHA Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery: Executive Summary *Journal of the American College of Cardiology*, Volume 64, Issue 22, Pages 2373-2405)
7. Review the ACC/AHA's recommendations regarding which medications to stop prior to undergoing surgery and which to continue.
8. **Establish peripheral vascular access.**
 - With few exceptions, IV access must be established prior to entering the OR.
 - Here are a few things to consider when deciding where to place an IV and what size catheter to place:
 - Identify the surgical site and try to steer clear of it. For example, if the patient is undergoing surgery in his left arm, don't place the IV in his left arm.
 - Consider how the patient will be positioned during surgery. For example, if the table will be rotated so that the patient's right side will be closest to you, then it might be helpful to place an IV on the patient's right side for accessibility.
 - Verify that there are no contraindications for a particular site, e.g. AV fistula.
 - Consider the type of surgery as well as the patient's underlying medical conditions. A healthy patient undergoing a minor procedure might only require one small PIV, whereas a patient with significant medical co-morbidities undergoing a more involved procedure might require several large bore IVs +/- a central venous catheter.
 - Obviously, a large catheter will not fit inside a tiny vessel. Knowing what size catheter to use for a certain vessel will come with experience. Ask for help!
 - Discuss the factors which determine the rate at which fluid can be given through an IV.
 - NEJM's Peripheral Intravenous Cannulation **video** may be viewed at:
<https://www.youtube.com/watch?v=qRWb9CJU0Yk>

(PART 2—MONITORS)

1. Review the ASA's definition of **standard monitors** and be able to place these monitors on patients.
 - Oxygenation: pulse oximetry
 - Ventilation: capnography (ETCO₂)
 - Circulation: non-invasive blood pressure (q5min); EKG
 - Temperature
 - Discuss the utility, effectiveness, and limitations of pulse oximetry.
 - Review several capnographs with a resident or attending. What do the waveforms and numbers indicate?
 - Regarding temperature, how do skin, nasal, esophageal, and rectal probes compare in terms of accuracy?
2. Discuss the indications, risks, and benefits associated with the following **invasive monitoring** techniques:
 - Arterial blood pressure
 - Central venous pressure
 - Pulmonary artery pressure
 - Transesophageal echocardiography
 - Discuss the possible sites for arterial lines and central venous catheters. Be able to draw a rough schematic for where the various types of central lines lie within the chest.
 - How accurately do the above monitors reflect a patient's volume status?
 - Discuss the relationship between pressure and volume in assessing cardiac performance
 - Participate in placement of arterial lines and central lines.

(PART 3—PATIENT POSITIONING)

1. Consider how patients are likely to be positioned for various surgical procedures:
 - Supine
 - Prone
 - Trendelenburg
 - Reverse Trendelenburg
 - Lateral decubitus
 - Lithotomy
 - Sitting (beach chair)
2. List the major risks/complications associated with each of the above positions.
3. Discuss the most commonly encountered nerve injuries related to positioning. How might these nerve injuries be prevented?

(PART 4—PHARMACOLOGY)

1. Review the **components of general anesthesia**:
 - Hypnosis
 - Amnesia
 - Analgesia
 - Muscle relaxation

2. Review the various **intravenous agents, inhaled agents, neuromuscular blocking drugs, opioids, benzodiazepines, barbiturates, local anesthetics, adjuvant multi-modal analgesics, etc.**

To get you started, here are the ones we encounter most often:

 - Intravenous agents: propofol, etomidate, ketamine, dexmedetomidine
 - Inhaled agents: nitrous oxide, desflurane, sevoflurane, isoflurane
 - Neuromuscular blocking drugs: succinylcholine, rocuronium, cisatracurium
 - Opioids: morphine, fentanyl, remifentanyl, sufentanil, hydromorphone, meperidine
 - Benzodiazepines: midazolam, lorazepam
 - Barbiturates: methohexital (we rarely see thiopental anymore)
 - Local anesthetics: lidocaine, bupivacaine, ropivacaine
 - For each of the above drugs, describe the **mechanism(s) of action**.
 - Which of the above properties (hypnosis, amnesia, analgesia, and muscle relaxation) do each of the above drugs exhibit? Note that some agents achieve more than one.

3. Be able to define the following terms:
 - Pharmacokinetics
 - Pharmacodynamics
 - Absorption
 - Distribution/ V_D
 - Metabolism
 - Excretion
 - Context-sensitive half time

4. **Intravenous anesthetics**
 - Discuss several situations in which you might choose one induction agent (propofol, etomidate, ketamine) over another.
 - Discuss the uses of dexmedetomidine.

5. **Inhalational anesthetics**
 - Define MAC (minimum alveolar concentration).
 - What are the MAC values for N₂O, desflurane, sevoflurane, isoflurane, and halothane?
 - List several patient factors known to increase or decrease MAC.
 - How do blood solubility, ventilation, and cardiac output influence speed of induction for inhaled agents?
 - Review the $F_A:F_I$ curve and discuss its implications.
 - Describe the general effects of inhalational agents on the cardiovascular, respiratory, and central nervous systems.

6. **Neuromuscular blocking drugs and reversal agents**
 - Classify the common neuromuscular blocking drugs as either depolarizing or non-depolarizing.
 - How do depolarizing and non-depolarizing NMB drugs differ in terms of mechanism of action?
 - Which of the NMB drugs are considered short, intermediate, and long-acting?
 - Name several contraindications against the use of succinylcholine.
 - Which NMB drug might you use during a rapid sequence induction? Why?
 - What is the purpose and mechanism of action of a reversal agent?
 - How does one gauge when to administer the reversal agent? In other words, when is a patient considered “reversible?”
 - Which other medication is nearly always administered along with reversal agents? Why?
 - What is sugammadex?
7. **Opioids**
 - Name several opioids commonly used during the perioperative period.
 - Describe the mechanism of action of an opioid.
 - How do morphine, fentanyl, hydromorphone, and meperidine compare in terms of potency?
8. **Benzodiazepines**
 - Midazolam is the benzodiazepine most commonly used during the perioperative period. What properties make midazolam a good choice?
 - Discuss which patients might or might not require/benefit from pre-op sedation?
9. **Barbiturates**
 - Name a few specific indications for methohexital.
10. **Local anesthetics**
 - Describe the mechanism of action for local anesthetics.
 - Be able to classify the various local anesthetics as either esters or amides.
 - Which class, esters or amides, is more closely associated with allergic reactions? Why?
 - Define the concept of pKa, how it relates to ionization, and why ionization is important for understanding local anesthetics.
 - What is the primary determinant for speed of onset?
 - What is the primary determinant of potency?
 - What is the primary determinant of duration?
 - What is Local Anesthetic Systemic Toxicity (LAST)? How does it manifest clinically? How is it treated?
11. Begin to familiarize yourself with the appropriate doses for the various medications.
12. What is sugammadex?

(PART 5—THE ANESTHESIA MACHINE)

1. Review the following components of the anesthesia machine.
 - Wall connectors/diameter index safety system
 - Oxygen cylinder/pin index safety system
 - Failsafe system
 - Oxygen flush valve
 - Vaporizers
 - One way inspiratory and expiratory valves
 - APL “pop-off” valve
 - Oxygen analyzer
 - Pressure gauges
 - Ventilator
 - CO2 canister
 - Scavenger system
 - Gas analyzer

2. Ask an anesthesia resident to go over/perform an anesthesia machine check with you.

(PART 6—ESTABLISHING AN AIRWAY)

Refer to PART 1 for information regarding **airway examination, as well as the predictors for difficult mask ventilation and difficult intubation.

1. Perform mask ventilation as much as possible. Learn how to open and close the APL/pop-off valve correctly while mask ventilating. Utilize oral and nasal airways.
2. When might you consider using a supraglottic airway (such as an LMA) over an ETT?
3. How does the MAC blade differ from the Miller blade? **Practice intubation** using both of these blades.
4. Define **Cormack-Lehane grade** views 1 through 4.
5. How is proper positioning of an ETT confirmed?
6. Explain how the presence of ETCO₂ might be deceiving in terms of proper ETT placement. In other words, what scenario may *not* be ruled out by the presence of ETCO₂ following intubation?
7. Utilize the various airway adjuncts including oral airways, nasal airways, the Glidescope, and the C-MAC.
8. What are several indications for either awake or asleep **fiberoptic intubation**?
9. Review the **ASA difficult airway algorithm**.

(PART 7—PHYSIOLOGY)

A. CARDIAC

1. Memorize and understand the following **equations**:

$$CO = HR \times SV$$

$$CI = CO/BSA$$

$$MAP = CO \times SVR$$

$$SVR = 80(MAP-CVP)/CO$$

$$PVR = 80(PAP-PAOP)/CO$$

$$EF = (EDV-ESV)/EDV$$

$$CPP = DBP-LVEDP$$

KEY:

CO = cardiac output

HR = heart rate

SV = stroke volume

CI = cardiac index

BSA = body surface area

MAP = mean arterial pressure

SVR = systemic vascular resistance

CVP = central venous pressure

PVR = pulmonary vascular resistance

PAP = (mean) pulmonary artery pressure

PCWP = pulmonary capillary wedge pressure

EF = ejection fraction

EDV = end-diastolic volume

ESV = end-systolic volume

CPP = coronary perfusion pressure

DBP = diastolic blood pressure

LVEDP = left ventricular end diastolic volume

2. Know the following **coronary anatomy**/blood flow distributions:
 - LAD: anterior wall; leads V1-V6
 - LCx: lateral wall; leads I, avL, V5, V6
 - RCA: inferior wall; leads II, III, avF
3. Recognize how each of the following conditions will manifest on EKG and be familiar with the appropriate therapies for each:
 - Paroxysmal supraventricular tachycardia
 - Atrial fibrillation
 - Myocardial ischemia
 - Hyperkalemia
 - 1st, 2nd, and 3rd degree heart block
4. Most coronary blood flow to the LV occurs during _____ (systole or diastole)?
Most coronary blood flow to the RV occurs during _____ (systole or diastole)?
5. Describe how each of the following helps to **optimize coronary perfusion**:
 - Maintain DBP
 - Decrease LVEDP
 - Decrease HR
6. Describe the relationship between LVEDP and SV, as depicted by the **Frank-Starling curve**.
7. Review the **pressure-volume curve** for a normal heart and how the appearance of this curve changes with the following valvular lesions:
 - Aortic stenosis
 - Aortic regurgitation
 - Mitral stenosis
 - Mitral regurgitation
8. For each of the above valvular lesions, what are the accepted goals/strategies in terms of preload, afterload, and heart rate? Discuss the importance of maintaining sinus rhythm for each of the lesions.
9. Review the components of a **CVP waveform**, including which occur during systole versus diastole and how each correlates with the cardiac cycle:
 - a: atrial contraction
 - c: tricuspid bulging

- x: atrial relaxation
- v: atrial filling
- y: early ventricular filling

10. **Pulmonary hypertension** is defined as a mean pulmonary artery pressure > 25 mmHg at rest. What are several etiologies for pHTN? How is pHTN treated/managed?
11. Review the following **vasopressors/inotropes** in terms of the mechanisms of action, major indications, and effects on the cardiovascular system. Refer to chart for guidance.

Drug	MOA	Indications	HR	CO
Phenylephrine				
Ephedrine				
Norepinephrine				
Epinephrine				
Vasopressin				
Dopamine				
Dobutamine				
Milrinone				

12. What is the **4-2-1** rule for fluid administration? Does it still apply? Discuss with a resident or attending the use of crystalloid versus colloid during surgery. Review volume administration strategies, risks and benefits for various types of surgeries...intraperitoneal, intrathoracic, vascular.

B. RESPIRATORY

1. Describe basic **airway innervation**.
 - Cranial nerves
 - Nose/nasopharynx: V (trigeminal)
 - Tongue/oropharynx: IX (glossopharyngeal)
 - Hypopharynx/larynx: X (vagus)
 - Superior laryngeal nerve
 - Internal branch: sensory above the glottis
 - External branch: motor to cricothyroid muscle
 - Recurrent laryngeal nerve:
 - Sensory below the glottis
 - Motor to all musculature except cricothyroid
2. Name the four **lung volumes** and four **lung capacities**. What is a normal V_T (per kg)? What is a normal vital capacity (per kg)?
3. Review the following definitions of **FRC**:
 - Residual volume + expiratory reserve volume
 - Volume of gas in lungs following normal expiration
 - Lung volume at which the outward elastic recoil of the chest is in equilibrium with the inward elastic recoil of the lungs
4. What factors alter FRC?
5. Explain the relationship between decreased FRC and hypoxemia. How do we counteract the reduction in FRC associated with lying supine (or in Trendelenburg) and inducing anesthesia?
6. Why do we **pre-oxygenate** patients prior to inducing anesthesia?

7. How might your anesthetic plan change in the setting of **obstructive lung disease**? **Restrictive lung disease**?
8. What are some risk factors/triggers for **bronchospasm**? How does it manifest intraoperatively? How is it treated?
9. What are some risk factors/triggers for **laryngospasm**? How does it manifest intraoperatively? How is it treated?

10. Memorize/understand the following **equations**:

$$PAO_2 = FiO_2 (P_{atm} - P_b) - (PACO_2/RQ)$$

$$C = V/P$$

$$C_D = V_T / (P_{peak} - PEEP)$$

$$C_S = V_T / (P_{plateau} - PEEP)$$

$$CaO_2 = 1.39(Hgb)(spO_2) + 0.003(PaO_2)$$

$$DO_2 = (CaO_2)(CO)$$

$$VO_2 = (CaO_2 - CvO_2)(CO)$$

$$SvO_2 = SaO_2 - [VO_2 / (Hgb)(CO)]$$

$$V_D = (PACO_2 - PECO_2) / PACO_2$$

KEY:

RQ = respiratory quotient

C = compliance

C_D = dynamic compliance

C_S = static compliance

DO₂ = oxygen delivery

CaO₂ = oxygen content in arterial blood

CvO₂ = oxygen content in venous blood

VO₂ = oxygen consumption

CaO₂ = oxygen content in arterial blood

SvO₂ = mixed venous oxygen saturation

V_D = dead space

11. Define **dead space** ventilation and provide several anesthesia-related examples.
12. Define **shunt** and provide several anesthesia-related examples.
13. Become familiar with the **CO₂ response curve** for a healthy awake patient. Review how the following drugs and conditions alter the body's ventilatory response to hypercarbia.
 - Inhalational agents
 - Opioids
 - Propofol, benzodiazepines
 - Hypoxia
14. Define **apneic threshold**. What is the apneic threshold for a healthy awake individual? How does the apneic threshold change in response to anesthesia?
15. Review the **oxygen dissociation curve**, including the causes of right and left shifts. Define p50. What is the normal p50 for an adult?
16. Review the anatomic locations/physiologic roles of the **central and peripheral chemoreceptors**.
 - Central chemoreceptors: located in medulla; respond mostly to changes in paco₂
 - Peripheral chemoreceptors: carotid bodies, aortic bodies; respond mostly to changes in paO₂
17. Explain the concept of hypoxic pulmonary vasoconstriction. What effects do the following drug classes have on HPV?
 - Volatile anesthetics
 - Opioids
 - Systemic vasodilators

NEURO

1. Name the three **intracranial components**.
2. Where and at what rate is CSF produced?
3. Explain the **Monroe-Kelly Doctrine**. Review with the **intracranial compliance curve**.
4. Memorize the equation for **cerebral perfusion pressure**: $CPP = MAP - ICP$
5. What is **CMRO₂**?
6. Explain the concept of **autoregulation** as it relates to cerebral blood flow. What is the range for autoregulation in a healthy adult? How does this range change with chronic hypertension?
7. How does **cerebral blood flow** change in response to the following conditions?
 - Hypoxia
 - Hypercarbia
 - Hyperthermia
 - Hypothermia
 To which of these factors is CBF most sensitive?
8. List several causes of elevated ICP.
9. Review the common clinical signs and symptoms associated with an **elevated ICP**:
 - Symptoms:
 - Headache
 - Nausea/vomiting
 - Altered mental status/loss of consciousness
 - Signs:
 - Papilledema
 - Periorbital bruising
 - CN VI palsy
 - Cushing's triad (HTN, bradycardia, disturbed respirations)
10. Be familiar with several **therapies used to lower ICP**:
 - Hyperventilation
 - Elevate head of bed
 - Mannitol (osmotic diuretic)
 - Volatile anesthetics
 - Propofol
 - Hypertonic saline
 - Extraventricular drain (EVD) or lumbar drain
 - Craniectomy
11. Review the following table, which explains the effects of various anesthetic drugs on CMRO₂, CBF, and ICP:

Drug	CMRO₂	CBF	ICP
Volatile agent	Decr	Incr	Decr
Nitrous oxide	Incr	Incr	Incr
IV agent (except ketamine)	Decr	Decr	Decr
Ketamine	Incr	Incr	Incr

(PART 8—PRINCIPLES OF MECHANICAL VENTILATION)

1. List the indications for intubation:
 - Inadequate oxygenation
 - Inadequate ventilation
 - Loss of airway reflexes/inability to protect against aspiration
2. Identify the major differences between spontaneous and mechanical ventilation.
3. Compare and contrast the various **modes of mechanical ventilation**, particularly volume control versus pressure control.
4. Define **PEEP**. How might PEEP benefit patients? For which patients might PEEP be contraindicated?
5. What are the **criteria for extubation**? How do these criteria differ for a patient who is emerging from general anesthesia in the OR versus one who has been mechanically ventilated in the ICU?
6. Become familiar with the **ARDSNet protocol**.

(PART 9—POST-ANESTHESIA CARE UNIT)

1. Review the general role of the PACU.
2. Define **phases 1 and 2 of recovery**:
 - Phase 1: high-level care for patients during emergence and awakening from anesthesia, until standard PACU criteria are met
 - Phase 2: lower-level care that ensures that the patient is ready to go home
3. What does “fast-track” mean? When might it be appropriate for patients to be fast-tracked?
4. When is physiologic monitoring (spO₂, BP, EKG) necessary during transport from the OR?
5. Which monitors should be placed on all patients upon their arrival to the PACU?
6. Describe basic elements of the report given by an anesthesia provider to PACU staff and participate in giving report:
 - Preoperative history
 - Pertinent intraoperative events (type of anesthesia, surgical procedure, blood loss, fluid replacement, antibiotic and other relevant medication administration, complications)
 - Expected postoperative problems
 - Anticipated need for PACU medication administration
 - Post-anesthesia orders
7. Criteria for discharge from the PACU vary somewhat across institutions. Discuss UPMC’s minimum discharge criteria with a resident, attending, or PACU nurse.
8. What is the **Aldrete recovery score**? How does this compare with the WAKE score used at UPMC?
9. Review the most frequently encountered PACU-related “issues”:
 - Pain
 - Agitation/emergence delirium

- PONV
 - Shivering and hypothermia
10. Review the following respiratory complications of anesthesia:
- Airway obstruction
 - Hypoventilation
 - Hypoxemia
11. Review the following circulatory complications of anesthesia:
- Hypotension
 - Hypertension
 - Arrhythmias

(PART 10—REGIONAL ANESTHESIA)

1. Define the following terms:
 - Regional anesthesia
 - Neuraxial anesthesia
 - Peripheral nerve blockade
2. Discuss several **indications** for neuraxial anesthesia:
 - Spinal
 - Low abdominal surgery
 - Perineal surgery
 - Lower extremity surgery
 - Planned cesarean delivery
 - Epidural
 - Low abdominal/perineal surgery (however, often sub-optimal due to segmental nature of block)
 - Supplemental to GA
 - Labor pain
3. Name several **contraindications** (either relative or absolute) to performing regional anesthesia.
 - Patient refusal
 - Infection at block site
 - Bleeding diathesis
 - ? increased ICP
4. Review the primary **determinants of spread for a spinal**:
 - Baricity
 - Patient position
5. Review the primary **determinants of spread for an epidural**:
 - Injection site
 - Volume
 - Concentration
6. Review the common **side effects/complications** associated with neuraxial anesthesia:
 - Hypotension
 - Bradycardia
 - Hypoventilation
 - Post-dural puncture headache
 - Urinary retention
 - Backache
 - Epidural hematoma or abscess

- Intravascular injection/LAST
 - “High” or “total” spinal
 - Failed or patchy block
7. Review the **anatomy of the spine**. What landmarks are used to determine the spinal level?
 8. Review the **structures that are traversed** during placement of an epidural and a spinal.
 - Skin/subcutaneous tissue
 - Supraspinous ligament
 - Interspinous ligament
 - Ligamentum flavum
 - Epidural space
 - Dura
 9. Review the commonly performed **peripheral nerve blocks** and why they are useful:
 - Interscalene
 - Supraclavicular
 - Infraclavicular
 - Axillary (and musculocutaneous)
 - Intercostal
 - Ilioinguinal, iliohypogastric
 - Femoral
 - Saphenous
 - Lateral femoral cutaneous
 - Obturator
 - Sciatic
 10. Explain the difference between a block for analgesia and a true surgical block.
 11. How do morbidity and mortality outcomes compare for general versus regional anesthesia?