Pediatric and Adult Anesthesiology Simulation Education

A Curriculum for Residents

Claire Sampankanpanich Soria
and Suraj Trivedi
Editors

Springer

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Preface

Welcome to *Pediatric and Adult Anesthesiology Simulation Education: A Curriculum for Anesthesiology Residents*. We decided to write this book after creating a new simulation curriculum at the University of California San Diego for our anesthesiology residents. As we created various adult and pediatric simulation cases, we realized we could share our cases and help other programs either upgrade their current list of simulation cases or start a new simulation program. We specifically included pediatric case examples as these can be difficult to find.

The operating room environment has become more complex with technological innovations. Successful outcomes depend on how well surgeons, anesthesiologists, nurses, and techs collaborate and work together as a team. In the style of the dynamic and fast-paced environment of the operating room, simulation training provides a safe, interactive, and educational platform where anesthesia residents and staff can enhance team performance.

The field of anesthesia has been a pioneer in the introduction of medical simulation into medical education and training. The field of anesthesia is a hands-on specialty that requires dexterity and proficiency with important technical skills such as advanced airway management, vascular access, neuraxial, and regional blocks [1]. Although the predominate use of simulation in anesthesia is to educate providers in crisis management, it is also used to teach routine management and refresh skills [2].

We believe this book is unique because of the breadth of specialties covered, including pediatric anesthesia. Pediatric anesthesia is a unique subspecialty within the field of anesthesiology, with nuances due to variations in physiology and anatomy, as well as the potential for congenital diseases and syndromes not encountered in daily practice of adult anesthesia. Our hope is that by providing a balance of adult and pediatric anesthesia, this book can help anesthesiologists refresh their knowledge and understanding of pediatric anesthesia and provide learners with an appreciation for the subtleties and delicate care that must be given to pediatric patients.

This book is designed to be used by both academic programs and private practice groups. We have divided the chapters into case-based formats with each chapter containing a scenario layout, useful equipment, major teaching points for an after-simulation debrief, and a learner evaluation form. This tiered education method will

assist learners in working though essential team-building skills, increasing their knowledge base, and finally having concrete items in which to further their professional skills.

Each chapter starts with a learning objective. The goals of the simulation are made clear to the learner and the educator. A sample simulator environment setup is then listed, with equipment, medications, and mannequin setup. Epps et al. has provided a list of mannequin-based simulation equipment and their setup [2]. We list equipment that we recommend for the specific simulation case. However, we do understand that depending on program preferences not every item may be available. Generally, standard anesthesia airway supplies are readily available, and larger, more specialized items such as defibrillator equipment can be either specially acquired or improvised. We use the SimMan 3G plus © (Laerdal) mannequin which enables us to remotely change vital signs and physical exam findings and allows learners to practice procedures such as intubations and intravenous line placement. However, an advanced mannequin or simulation lab is not a requirement to run a successful simulation program, and often all that is required is a little creativity and understanding.

Each chapter presents the simulation case before launching into the case progression, detailing how the simulated patient's vital signs, physical exam findings, and clinical picture change over the course of the simulation. There are several pathways presented to the educator depending on what clinical choices the learner makes. Each chapter has a master checklist of items the learner should accomplish during the course of the simulation. We encourage educators to gently assist learners in achieving these goals as these can be used for critical feedback at the end of a simulation session. We close each chapter with a section summary and important teaching points. In addition to the goals list, these often provide valuable educational experiences to the learner.

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Chapter 1
Automatic Implantable Cardioverter Defibrillator (AICD) Misfiring (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss the anesthetic management of automatic implantable cardioverter defibrillator (AICD)/pacemaker during non-cardiac surgery.
2. Discuss indications for reprogramming an AICD/pacemaker preoperatively.

Simulator Environment

1. Location: operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 x 18 Gauge (G) peripheral intravenous line (PIV), radial arterial line, foley catheter.
   (c) Monitors: non-invasive blood pressure cuff, 5-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide (ETCO2).
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG, radial arterial line.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator
   (e) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy opening instrument.
2. Circulator nurse
   (a) The nurse is busy helping to open trays.
3. Surgeon
   (a) The surgeons are focused, trying to operate as quickly as possible.

Scenario Development

1. Background
   (a) You are the anesthesiologist starting a level one exploratory laparotomy in an 82-year-old man who was found down on the sidewalk after being hit by a car in a hit-and-run accident. There is no known medical information about the patient. En route, the patient was noted to be vomiting blood and has a tense, tender abdomen that is enlarging. There is concern for intra-abdominal bleeding, possibly a splenic or liver laceration. The patient has been hypotensive 70s/40s requiring repeated fluid boluses.
   (b) There was no time to stop in the trauma bay. The patient was intubated in the field by Emergency Medical Services (EMS) and brought directly to the OR for resuscitation.
2. Phase 1: electrocautery interference with cardiovascular implantable electronic device (CIED).
   (a) Initially, the learner will observe regular pacemaker spikes on the EKG monitor. After removing the patient's gown, the learner will see a CIED in

the patient's left chest. The learner should try to gather more information about what type of device this is:

(i) Looking in the patient's chart for previous imaging such as a chest x-ray (CXR) that may indicate: number of leads, location of leads, and whether shock coils are present indicating this is an AICD.
(ii) Reviewing patient's chart for records describing the device:

1. Type of device (AICD or pacemaker; number and location of leads)
2. Manufacturer
3. When it was placed
4. Indication for placement
5. When it was last interrogated
6. Whether patient is pacemaker dependent
7. Battery life
8. Lead integrity
9. Mode (default settings; response to magnet placement and magnet removal)

(b) The learner should place an arterial line for closer hemodynamic monitoring in the setting of hypotension and presumed significant intra-abdominal bleeding, and the new finding of a CIED.
(c) The learner will notice that when the surgeons begin electrocautery, especially high up in the abdomen as they work on the spleen and liver, that there is absent cardiac output – no beats on the arterial line or pulse oximeter waveform tracings, a drop in blood pressure, and inability to interpret the EKG due to signal interference.
(d) The learner should try to troubleshoot:

(i) Ask surgeons to minimize electrocautery use and to use bipolar instead of monopolar if possible.
(ii) Note distance between CIED and source of electromagnetic interference (ideally >12 inches apart).
(iii) Call for automated external defibrillator (AED) to be brought to operating room (OR). Place pads on patient pre-emptively.
(iv) Ensure adequate oxygenation and ventilation.
(v) Ensure normal electrolytes.
(vi) Support hemodynamics: consider pharmacologic inotropic support (dopamine, epinephrine, etc.) and vasopressors (phenylephrine, etc.) to maintain adequate cardiac output and mean arterial pressure.
(vii) Consider placing a magnet over the device. Possible results:

1. Pacemaker: may place in an asynchronous pacing mode.
2. AICD: may disable anti-tachycardia function.

3. Phase 2: misfiring of AICD / pacemaker malfunction
   (a) The surgeons will continue to work as quickly as possible with bipolar cautery, but cannot control the distance between their cautery and the CIED, since there are splenic and liver lacerations requiring repair.
   (b) If the learner does not place a magnet over the device:
      (i) The patient's body will start to jolt/shake – the AICD will discharge and shock the patient.
      (ii) The learner should immediately place a magnet over the device, now knowing it is an AICD, to try to deactivate the anti-tachycardia function.
   (c) If the learner does place a magnet over the device:
      (i) The pacemaker will continue to pace erratically and eventually go into ventricular fibrillation.
      (ii) The learner should defibrillate the patient.

Scoring Rubric

Table 1.1 Scoring rubric for case scenario on Automatic Implantable Cardioverter Defibrillator Misfiring

Topic: Automatic Implantable Cardioverter Defibrillator (AICD) Misfiring (Adult)		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Aicd evaluation		
Looks at CXR to obtain additional device information: Number of leads, location of leads, presence of shock coil		
Reviews medical records for device information: Type of device (defibrillator vs. pacemaker), number/location of leads, manufacturer, date of placement, indication for placement, date of last interrogation, battery life, lead integrity, pacemaker dependence / percentage of time paced, mode (default settings, response to magnet placement and magnet removal)		
Obtains history about cardiac workup: Recent visit to cardiologist, medications (compliance, up/down-titration of dosing), recent echocardiogram, surgical repair		
Places awake arterial line for closer hemodynamic monitoring		
Sends labs for complete blood count (CBC), coagulation panel, basic metabolic panel (BMP), and type and cross		
Device malfunction		
Identifies electrocardiogram (EKG) artifact when electrocautery is used		
Places magnet over device site to place in asynchronous pacing mode of pacemaker or disable anti-tachycardia function of AICD		

Table 1.1 (continued)

Topic: Automatic Implantable Cardioverter Defibrillator (AICD) Misfiring (Adult)		
Identifies hemodynamic instability: Hypotension, dropped beats, absent pulse associated with electrocautery use		
Recognizes occurrence as device malfunction		
Asks surgeons to minimize duration of electrocautery use and to use bipolar instead of monopolar as much as possible		
Ensures adequate oxygenation and ventilation		
Ensures normal electrolytes		
Calls for AED to be brought to OR		
Places AED pads on patient		
Supports hemodynamics with inotropes and/or pressors, maintains adequate MAP		
Identifies arrhythmias and cardioverts as indicated		

Summary of Clinical Teaching Points

What are cardiac implanted electrical devices (CIED)? [1, 2]

- Pacemakers
- AICDs: Automatic Implanted Cardiac Defibrillators
- Classically, the components are a battery and electric circuitry contained with a pulse generator which then transmit electrical impulses via leads that are in physical contact with the heart.
  - Single chamber device is usually a single lead in the right ventricle
  - Dual chamber device is typically one lead in right atrium and one lead in the right ventricle
  - Biventricular pacemaker is typically 3 leads in the right atrium, right ventricle, and coronary sinus, which allows pacing of the left ventricle and enables synchronization of right and left ventricles
- Leadless pacemakers are placed directly in the heart so there is no need for a surgical pocket or insulated wires

What do you need to know pre-operatively?

- Type of device (AICD or pacemaker; number and location of leads)
- Manufacturer / model / serial number
- When it was placed
- Indication for placement
- When it was last interrogated
- Whether patient is pacemaker dependent
  - How often (percentage) of time is patient paced?
  - What happens when the patient is not paced?

- Has the AICD fired?
  - How often?
- Battery life
- Lead integrity
- Mode (default settings; response to magnet placement and magnet removal)

How do you find this information?

- Device interrogation report
- Cardiologist clinic note
- Call the manufacturer representative
- Check the patient's wallet for a device card

What could go wrong, generally?

- The device can be damaged intraoperatively.
- The device can deliver a cardioversion when it shouldn't.
- The device can fail to cardiovert/pace when it should.
- The device can stop working completely.

What could go wrong, specifically?

- If the patient is pacemaker-dependent and the battery dies or a lead breaks, the patient can go into cardiac arrest. The anesthesiologist will need to initiate advanced cardiac life support (ACLS) and start chest compressions. The anesthesiologist may need to provide external pacing using an automated external defibrillator pacing pads or may need to start internal pacing using transvenous pacing leads.
- An AICD may misinterpret electrocautery as a tachyarrhythmia and misfire, delivering a shock to the patient unnecessarily. Repeated shocks can lead to myocardial ischemia, patient movement during surgery, and trauma to the skin, muscle, and soft tissue.
- Pacemaker function may become altered by electrocautery, leading the pacemaker to pace erratically or not at all.

What should you do with an AICD or pacemaker in an emergency surgery?

1. Identify that the patient has a CIED.
2. Proceed to the operating room for emergency surgery.
3. Place defibrillator pads on the patient's chest to be used as back-up pacing or external cardioversion if necessary.
4. For a known or suspected AICD, tape a magnet to the patient's skin directly overlying the device.
5. Post-operatively, remove the magnet and the defibrillator pads, assuming the patient was hemodynamically stable and there were no adverse intraoperative events relating to the device.
6. Consult Cardiology or device representative for device interrogation to ensure it is functioning normally.

How do you troubleshoot a device? [1, 2]

- Ask surgeons to minimize electrocautery use and to use bipolar cautery instead of monopolar if possible.
- Note the distance between the CIED and the source of electromagnetic interference (ideally >12 inches apart).
- Call for an AED to be brought to OR. Place defibrillator pads on patient pre-emptively.
- Ensure adequate oxygenation and ventilation.
- Ensure normal electrolytes.
- Support hemodynamics: consider pharmacologic inotropic support (dopamine, epinephrine, etc.) and vasopressors (phenylephrine, etc.) to maintain adequate cardiac output and mean arterial pressure.
- Consider placing a magnet over the device. Possible results:
  - Pacemaker: will likely place in an asynchronous pacing mode.
  - AICD: will likely disable anti-tachycardia function.

What do magnets do to a CIED?

- Pacemaker: would expect it to place device in an asynchronous pacing mode (DOO or VOO)
- AICD: would expect it to disable anti-tachycardia function
- But every device is different and is not standardized across models even by the same company
- Most definitive is to re-program the device
  - Cardiologist/electrophysiologist
  - Device representative
  - Cardiac anesthesiologist
- When you remove the magnet, the device may not revert back to default mode
  - Safest to interrogate the device post-operatively

Can you leave a patient in an asynchronous pacing mode?

- Asynchronous pacing mode is Ideal for the operating room because you don't worry that electrosurgical interference will interfere with pacemaker function
- Use caution when leaving a patient in DOO or VOO mode because there is no sensing and no inhibition of the native rhythm
- The danger is a situation where the pacemaker paces on a T wave (called R on T phenomenon), which can lead to cardiac arrest due to an arrhythmia like ventricular tachycardia or ventricular fibrillation.
  - The "R-on-T phenomenon"is the superimposition of an ectopic beat on the T wave of a preceding beat.
  - The native heart rate may exceed the programmed rate.
  - There may be frequent PVCs or PACs. Repolarization from PAC or PVC (T wave) can occur at the same moment that pacemaker discharges (R wave).
- In DOO or VOO mode, you are the sensor

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Chapter 2
Amniotic Fluid Embolism (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Review the signs and symptoms of amniotic fluid embolism.
2. Review risk factors for occurrence of amniotic fluid embolism.
3. Discuss intraoperative management of amniotic fluid embolism.

Simulator Environment

1. Location: operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 x 20 Gauge (G) peripheral intravenous line (PIV).
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter.
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG, radial arterial line.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator

Actors

1. OR circulator
   (a) The circulator nurse (RN) is busy getting equipment for the surgeon and trying to set up the suction and curettage equipment.
2. OR scrub
   (a) The scrub tech is busy trying to figure out how the new curettage equipment works.
3. Surgeon
   (a) The obstetrics/gynecology (OB/GYN) surgeon is struggling to control the bleeding so they can obtain an adequate surgical view. They are having a difficult time trying to find the source.
4. Anesthesia tech

Scenario Development

4. Background:
   (a) You are the anesthesiologist who has been handed a level 1 dilation and evacuation. The patient is brought to the operating room (OR) front desk by the floor nurse. On exam, you note that the patient is a 38-year-old woman, normal body mass index (BMI), with no known past medical history (PMH), reassuring airway exam, who has 1 x 20 G PIV and is currently receiving 1 unit (U) of packed red blood cells (PRBC) infusing over 1 hour on an Alaris pump.
   (b) On sign-out, the floor nurse reports that the patient was admitted overnight. She is 22 weeks pregnant and recently underwent a failed dilation and evacuation at a Planned Parenthood. However, there was excessive bleeding, so

she was sent to your tertiary care hospital for higher level care. The patient was continuing to bleed "a little bit more heavily" overnight, so they transfused her 1 U PRBC, which is running now. She was only type and crossmatched for 2 U PRBCs total. The other unit is in the blood bank.

(c) Current vital signs: systolic blood pressure (SBP) 150 s, oxygen saturation (SpO_2) 98% on room air, heart rate (HR) 110 s.

5. Phase 1: induction, intubation, and line placement

   (a) The learner should perform a cautious induction and intubation to maintain hemodynamic stability.
   (b) The learner should establish larger bore PIV access and may consider an arterial line placement.
   (c) The learner should check a recent hemoglobin/hematocrit (Hb/Hct), either through a venous blood gas (VBG) or arterial blood gas (ABG).

6. Phase 2: development of disseminated intravascular coagulation

   (a) Worrisome findings:

      (i) The surgeons will report that they are having a hard time getting a good view of the surgical field and identifying the source of the bleeding because there is so much blood obstructing their view.
      (ii) There will be frequent suctioning as well as trouble with the evacuation/curettage equipment that frustrates the surgeons.
      (iii) The surgeons will note that the blood looks very "watery."
      (iv) The anesthesia tech will also report that that Tegaderm dressing over the PIV sites is very loose and there's blood underneath it that's making the Tegaderm peel off.
      (v) The patient will become increasingly hemodynamically unstable, with worsening tachycardia and hypotension, and will start to desaturate and have a decline in ETCO2.

   (b) At this point, the learner should have a high suspicion for disseminated intravascular coagulation, possibly iatrogenic due to not maintaining a balanced transfusion of PRBCs along with platelets and clotting factors, or due to amniotic fluid embolism.

      (i) The learner should initiate massive transfusion protocol and place a central line. The arms are tucked. The learner may also consider placing a large PIV in the external jugular vein if they do not have enough time/resources to place a central line.
      (ii) The learner should initiate a balanced transfusion of PRBCs, fresh frozen plasma (FFP), platelets, and consider cryoprecipitate.
      (iii) The learner should consider sending a TEG to evaluate for coagulopathy.

7. Phase 3: hemodynamic collapse from right heart failure due to amniotic fluid embolism
   (a) The patient's vital signs will change: tachyarrhythmias or bradyarrhythmias with worsening hypotension.
   (b) If the learner does not intervene quickly by initiating inotropic support (epinephrine, dopamine, etc.), the patient will go into cardiac arrest.
   (c) The learner should have a high suspicion for right heart failure due to amniotic fluid embolism and provide hemodynamic support with pressors and inotropes.
   (d) The learner may consider placing a trans-esophageal echocardiogram probe to evaluate right heart failure or may treat presumptively.

Scoring Rubric

Table 2.1 Scoring rubric for case scenario on Amniotic Fluid Embolism

Topic: Amniotic Fluid Embolism		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Hemorrhage		
Surveys the surgical field, drapes, and wet laps		
Establishes an estimated blood loss so far		
Sends repeat arterial blood gas (ABG) and complete blood count (CBC) labs		
Establishes larger bore peripheral IV (PIV) or central line access		
Transfuses packed red blood cells (PRBCs), fresh frozen plasma (FFP), platelets, and cryoprecipitate in balanced ratios		
Initiates massive transfusion protocol		
Calls for help		
Calls for Belmont or rapid infuser		
May send thromboelastogram (TEG)		
Identifies "watery blood" and bleeding around PIV sites as signs of disseminated intravascular coagulation		
Right heart failure		
Evaluates for other causes of hypotension and arrhythmias		
May perform TEE to evaluate acute heart failure		
Communicates hemodynamic changes to surgeons		
Establishes amniotic fluid embolism as cause of acute right heart failure		
Support hemodynamics with inotropes (dopamine, epinephrine, etc.) and pressors		
Hyperventilates with 100% FiO2		

Summary of Clinical Teaching Points

What is amniotic fluid embolism (AFE)? [1, 2, 3]

- Rare occurrence in pregnancy
- Fetal amniotic fluid enters maternal circulation
  - Breach in physical barriers between maternal and fetal compartments: endocervical veins, uterine trauma, placental attachment
  - Pressure gradient favoring amniotic fluid entering from uterus to maternal circulation
  - Can occur as late as 48 hours postpartum
- Previous thinking for mechanism of action: physical obstruction of pulmonary circulation
- Current thinking for mechanism of action: inflammatory reaction like an anaphylactoid reaction in the pulmonary vasculature
  - Intracardiac

    Hemodynamic collapse from right heart failure
  - Extracardiac/systemic

    Coagulopathy
    Noncardiogenic pulmonary edema

What are the phases of progression of amniotic fluid embolism? [1, 2, 3]

1. Phase 1
   (a) Amniotic fluid enters maternal circulation, leading to the release of inflammatory mediators
   (b) This results in pulmonary artery vasopasm and right ventricular strain, thereby causing hypotension and hypoxemia
   (c) Systemic vasodilation also occurs
   (d) This lasts approximately 30 minutes
2. Phase 2
   (a) Phase 2 develops assuming the patient survives phase 1
   (b) Left ventricular failure occurs: the right ventricle fails and the interventricular septum bows into the left ventricle, impeding left ventricular diastolic and systolic function. This causes worsened hypotension, decreased cardiac output, and increased pulmonary artery pressure.
   (c) Coagulopathy and massive hemorrhage ensue

When should you suspect amniotic fluid embolism?

- Acute hypotension or cardiac arrest
  - Right heart strain/failure

Acute increase in pulmonary vascular resistance
Not due to a physical clot per se, but an inflammatory reaction resulting in increased pulmonary vascular resistance

- Sudden cardiovascular collapse with profound systemic hypotension and arrhythmias

- Acute hypoxia (dyspnea, cyanosis, respiratory arrest)
  - Increased dead space; severe ventilation/perfusion mismatch

    Ventilating but not perfusing, due to obstruction in pulmonary artery blood flow
    Decline in end tidal carbon dioxide ($ETCO_2$), but a rise in arterial carbon dioxide ($PaCO_2$)

  - Noncardiogenic pulmonary edema, cyanosis, dyspnea, respiratory arrest, pulmonary edema, acute respiratory distress syndrome
- Coagulopathy (usually disseminated intravascular coagulation) and severe hemorrhage
  - Mechanism: activation of clotting cascade in pulmonary vasculature that leads to a combination of microvascular thrombosis, vasoconstriction, and consumptive coagulopathy
- Associated with onset of labor, cesarean section, within 30 minutes postpartum, or with abortion
  - Late presentations of amniotic fluid embolism include: amniotic fluid and fetal debris trapped in uterine veins at the time of delivery, that are then released into circulation during uterine involution
- Neurologic: altered metal status, hypoxic encephalopathy, seizures
- Diagnosis of exclusion
  - No specific laboratory tests to make diagnosis of amniotic fluid embolism
  - In clinical setting, not able to reliably differentiate maternal versus fetal squamous cells

What are risk factors for amniotic fluid embolism? [1, 2, 3]

Table 2.2 Risk factors for amniotic fluid embolism

Increased Risk	Not Associated with Increased Risk
Maternal age > 35 years old	Advanced maternal age in first pregnancy
Cesarean delivery	Primigravid
Forceps-assisted and vacuum-assisted vaginal deliveries	High parity
Placenta previa	Multiple gestations

Table 2.2 (continued)

Increased Risk	Not Associated with Increased Risk
Eclampsia	Chorioamnionitis
Fetal distress	Fetal macrosomia
Polyhydramnios	
Cervical laceration	
Uterine rupture	

How do you assess the acuity and severity of pulmonary hypertension?

- Acute pulmonary hypertension
  - Right ventricle has no time to compensate, resulting in complete right ventricular collapse
  - Right ventricle is not composed of the same myocytes as left ventricle, so it is not designed to handle high pressures, especially so suddenly
- Chronic pulmonary hypertension
  - Honeymoon phase:

    Right ventricle has time to compensate by dilating and hypertrophying
  - Challenge: thicker myocardial wall is harder to perfuse, so over time, it will fatigue and fail

What are the mechanics of pulmonary hypertension and why do they matter?

- Paradoxical septal movement or flattened interventricular septum: why is this significant? When the interventricular septum bows from the right ventricle into the left ventricle, this causes impaired right ventricular contractility and decreased left ventricular diastolic filling (decreased compliance).
- #1: Decreased cardiac output lowers aortic systolic and diastolic pressure, leading to decreased coronary perfusion pressure, then ischemia/infarction of the right ventricle and left ventricle, further impairing right ventricular and left ventricular contractility, and ultimately spiraling the patient into cardiac arrest.
- #2: Decreased pulmonary blood flow results in decreased oxygenation and exchange of carbon dioxide, causing decreased oxygenation of blood going to the systemic circulation. This leads to further hypoxemia, hypercarbia, and acidosis, which then continues to raise pulmonary vascular resistance and exacerbate contractility of myocardial cells. This further impedes pulmonary blood flow and right ventricular and left ventricular output.
- #3: Right ventricular failure leads to tricuspid regurgitation, left atrial dilation, high left atrial pressures. Such pressures result in poor passive drainage of venous return from the superior vena cava and inferior vena cava into the left atrium, decreasing relative preload and further decreasing cardiac output.

How is amniotic fluid embolism medically managed?

- Primarily resuscitative, supportive care measures
- Airway / Breathing
  - Ensure adequate oxygenation and ventilation
  - Intubate and initiate positive pressure ventilation with 100% FiO2
- Circulation
  - Stabilize hemodynamics with vasopressors and inotropes
  - Fluid resuscitate
  - Phenylephrine or other vasoconstrictors are a good choice in the early phase of hypotension secondary to systemic vasodilation
  - Initiate inotropes (e.g. dopamine, epinephrine, norepinephrine) early to avoid the spiral of doom caused by right heart failure
  - Correct coagulopathy

    Blood products: packed red blood cells (PRBCs), fresh frozen plasma (FFP), platelets, cryoprecipitate should be considered early
    Factor VII has been used, but may increase the risk of intravascular thrombosis (stroke, myocardial infarction)

How is amniotic fluid embolism managed surgically?

- Manual exploration to remove fragments of retained placenta or membranes
- Identify and repair cervical or uterine lacerations
- If there is profuse bleeding and pharmacologic treatment is not improving uterine bleeding, patient may require hysterectomy

What is disseminated intravascular coagulation (DIC) and how is it managed? [1, 2, 3]

- Signs and symptoms
  - White blood cell (WBC) count may be elevated
  - Hemoglobin (Hb)/Hematocrit (Hct) may be low
  - Prolonged Prothrombin Time (PT) and Partial Thromboplastin Time (PTT)
  - Decreased fibrinogen level
  - Thrombocytopenia is rare
  - Frequently associated with severe hemorrhage
- Differential diagnoses
  - Amniotic fluid embolism
  - Anaphylaxis
  - Inadequate/imbalanced transfusion resuscitation
  - Dilutional coagulopathy from fluid resuscitation

- Management
  - Prioritize transfusing packed red blood cells (PRBCs) to maintain tissue oxygen delivery
  - Transfuse fresh frozen plasma (FFP), platelets, cryoprecipitate
  - Cryoprecipitate benefits: replenishes clotting factors with less volume, higher concentration than fresh frozen plasma. Fibronectin may facilitate removal of cellular and particulate matter like amniotic fluid debris.

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Chapter 3
Anaphylaxis (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Review the signs and symptoms of anaphylaxis.
2. Discuss medical management of anaphylaxis.

Simulator Environment

1. Location: ICU room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 x 20 Gauge (G) peripheral intravenous line (PIV), radial arterial line.
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter, radial arterial line.
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG, radial arterial line.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator

Actors

1. Intensive care unit (ICU) nurse
   (a) The ICU nurse helpful and able to work on larger bore PIV access.
2. ICU physician
   (a) The ICU physician is nervous and struggling to obtain a good view to intubate.
   (b) The ICU physician is in a bit of denial about the patient being in anaphylaxis and the etiology.

Scenario Development

1. Background
   (a) You are the anesthesiologist on-call overnight and are paged STAT to the bedside to help intubate an ICU patient. Upon arrival, you find a crowded room and cardiopulmonary resuscitation (CPR) including chest compressions and bag mask ventilation in progress. The ICU attending tells you that they have been trying to intubate the patient multiple times but keep getting a floppy epiglottis and a grade 3 view.
   (b) Upon closer examination, you notice that the patient's gown and bed are covered in bright red blood. The patient's lips and tongue are very swollen. The tongue is so large that it is coming out of the mouth to the side. The face, head, and neck are engorged and erythematous.
2. Phase 1: anesthesia paged for difficult intubation
   (a) The learner should proceed to intubate as soon as possible. They should prepare for difficult laryngoscopy and may consider using a smaller sized

ETT given the severe swelling: 6.0 cuffed ETT, Glidescope vs. direct laryngoscopy, Bougie.

(b) The learner will be able to obtain a good view but will be required to downsize to a 6.0 cuffed ETT, which will be difficult to pass without some manipulation due to airway edema.

(c) The learner will observe that it is difficult to ventilate the patient. The bag feels tight when manually bagging and there is limited chest rise. There is bilateral wheezing on auscultation.

3. Phase 2: management of anaphylaxis

(a) The learner should request more information about the patient: this is a 65-year-old man with hepatitis C and alcoholism who was admitted for hematemesis. Prior to going into cardiac arrest, the patient had been receiving a blood transfusion of fresh frozen plasma (FFP) after already receiving packed red blood cells (PRBCs). The ICU resident was in the middle of placing a radial arterial line when they noticed that the patient was nonresponsive. The patient subsequently desaturated and became severely hypotensive, and then pulseless.

(b) The learner will be asked by the ICU physician for advice on what they think caused the difficult airway and the cardiac arrest. The learner should have a high suspicion for anaphylaxis given the respiratory arrest, angioedema, hemodynamic instability, and triggering agent (e.g. FFP infusion).

(c) The learner should initiate appropriate treatment:

(i) Ensure adequate oxygenation and ventilation.
(ii) Administer epinephrine – may consider an infusion versus boluses.
(iii) Supportive care: hemodynamic support with fluid boluses, pressors, and inotropes as needed.
(iv) Administer H1-receptor antagonist (diphenhydramine) and H2-receptor antagonist (famotidine).
(v) Treat wheezing/bronchospasm as needed with albuterol.
(vi) Send serum tryptase levels within 1 hour.

(d) The learner should work to identify possible causes of anaphylaxis and seek to discontinue the triggering agent.

(i) Example: blood product transfusion should be discontinued and bag saved to send to blood bank for testing. Confirm compatibility.

Scoring Rubric

Table 3.1 Scoring rubric for case scenario on Status Epilepticus

Topic: Status Epilepticus			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Respiratory failure			
Management	Intubates the patient in a timely fashion		
	Prepares equipment for difficult intubation (Bougie, Glidescope, fiberoptic bronchoscopy, smaller sized endotracheal tube (ETT))		
	Downsizes ETT due to airway edema		
	Identifies poor compliance while manually bagging patient		
	Auscultates bilateral breath sounds		
	Identifies bilateral expiratory wheezing and suspects bronchospasm		
Anaphylaxis			
Evaluation	Identifies physical findings of anaphylaxis: Angioedema of lips and tongue; bronchospasm		
	Obtains further history about patient (past medical history (PMH), recent medications, recent blood transfusions)		
	Correctly defines anaphylaxis: Mucocutaneous reaction plus at least 2 of the 3 – Respiratory symptoms (hypoxemia, bronchospasm, dyspnea), cardiac symptoms (hypotension, arrhythmias), and gastrointestinal symptoms (nausea, vomiting, abdominal pain, diarrhea)		
Management	Discontinues triggering agent: Stops the blood transfusion and changes out to fresh intravenous (IV) tubing		
	Ventilates with 100% fraction of inspired oxygen (FiO_2)		
	Administers epinephrine 1 mg IV		
	May initiate epinephrine infusion		
	Administers albuterol via ETT		
	Administers H1-receptor antagonist: Diphenhydramine 50 mg IV		
	Administers H2-receptor antagonist: Famotidine 20 mg IV		
	Administers steroids: Hydrocortisone 100 mg IV		
	Notifies blood Bank and sends blood product sample back for testing		
	Double checks blood product cross matching.		
	Draws labs, especially serum tryptase		

Summary of Clinical Teaching Points

What are the criteria for diagnosis of anaphylaxis? [1, 2]

Suspect anaphylaxis when at least two of the following occur within minutes to hours after exposure to a possible allergen.

- Mucocutaneous
  - Involvement of skin and mucosal tissues (e.g. hives, itching, flushing, swollen lips/tongue/uvula)
- Respiratory
  - Shortness of breath (dyspnea)
  - Bronchospasm, wheezing
  - Stridor
  - Hypoxemia
- Cardiovascular
  - Hypotension
  - Hypotonia
  - Syncope
  - Urinary incontinence
- Gastrointestinal
  - Abdominal pain
  - Nausea/vomiting

How is anaphylaxis managed? [1, 2]

- Ensure adequate oxygenation and ventilation: intubation, 100% FiO2.
- Establish vascular access.
- Administer epinephrine: may consider an infusion versus boluses.
  - Preferred route intravenous.
  - If unable to obtain IV access, may administer epinephrine intramuscular.
- Supportive care: hemodynamic support with fluid boluses, pressors, and inotropes as needed.
- Administer H1-receptor antagonist (diphenhydramine) and H2-receptor antagonist (famotidine).
- Treat wheezing/bronchospasm as needed with albuterol.
- Send serum tryptase levels within 1 hour.
- Discontinue triggering agent.

What are common causes of anaphylaxis intraoperatively?

- Medications
  - Steroidal, non-depolarizing neuromuscular blockers (e.g. rocuronium)
  - Antibiotics

- Blood products
  - Most risky: fresh frozen plasma (FFP) which contains plasma proteins
- Latex

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Chapter 4
Anterior Mediastinal Mass (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Describe preoperative workup for anterior mediastinal mass.
2. Describe induction considerations for anterior mediastinal mass.
3. Discuss anesthetic management intraoperatively for biopsy versus resection of anterior mediastinal mass.

Simulator Environment

1. Location: operating room in a children's hospital
2. Manikin setup:
   (a) Age: child
   (b) Lines: 1 x 22 Gauge (G) peripheral intravenous line (PIV) in hand
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter
3. Medications available: normal saline, propofol, succinylcholine, rocuronium, epinephrine, dopamine, albuterol, fentanyl, ketamine, dexmedetomidine. Sugammadex is not available.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Lines: 18/20/22 G PIV catheters, tourniquet, IV pigtail and flush, arterial line setup.
   (c) Crash cart with defibrillator
   (d) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy opening trays. They are helpful at providing manual labor assistance, such as repositioning the patient or bringing the crash cart into the room.
2. Circulator nurse
   (a) The nurse is helpful but nervous. This hospital does not take care of a lot of kids with anterior mediastinal masses, so she's not aware of all the precautions and complications that can occur.
3. Surgeon
   (a) The surgeon is on the phone at the computer dictating their operative note from a previous patient. It takes a few tries to get their attention.
4. Anesthesia tech
   (a) The anesthesia tech is helpful at handing equipment to the anesthesiologist in a timely fashion.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist starting a case on a Friday at 6 pm of an 8-year-old, 27 kilogram (kg) girl with a newly diagnosed anterior mediastinal mass who is now undergoing resection.
   (b) Preoperative history: ex-full term; healthy; doing well in school, keeping up with peers, eating well, growing well; mild asthma exacerbated by pollen

and URIs. Parents brought her into the emergency department (ED) a week ago because she had been having a chronic feeling of difficulty breathing when lying flat. She normally plays in a soccer league but lately has been more tired than usual. At night, she sleeps most comfortably on her right side.

(c) Preoperative physical: well-nourished child, breathing comfortably when sitting upright in chair, but when lays flat, feels like she's suffocating.

(d) Preoperative vital signs: blood pressure (BP) 110/65, heart rate (HR) 87, oxygen saturation (SpO2) 100% on room air (RA), temperature (T) 37 degrees Celsius.

(e) Preoperative labs: potassium (K) 4.0, creatinine (Cr) 0.8, hemoglobin (Hb) 12.0, platelets (Plt) 220.

(f) Preoperative transthoracic echocardiogram (TTE) and computed tomography (CT) scan thorax with contrast (only available if the learner asks for these reports specifically): the mass is very large and causing severe compression of the distal trachea. The CT scan was done with the patient under minimal sedation with a thick pillow to elevate her head so she could breathe better. TTE was notable for moderate-severe compression of the left ventricle when lying supine, and mild-moderate compression with the patient upright. Otherwise, good right ventricular (RV) systolic function and impaired left ventricular (LV) diastolic filling and systolic function from compression.

2. Scenario development

(a) Phase 1: inability to ventilate after induction.

(i) The patient will complain that she does not feel good lying flat on her back. She will be anxious, tearful, and scared.

(ii) The learner should ask the patient what position is most comfortable for her. Options include allowing the patient to sit upright until she is asleep, or raising the head of the bed and providing pillows while she lies down.

(iii) The learner may do a debrief with the operating room (OR) team.

1. Alert everyone to the fact that this patient may be difficult to ventilate, even if they have a normal airway exam and are easy to intubate, due to compression / mass effect on the tracheobronchial tree.
2. This patient may become hemodynamically unstable and decrease her cardiac output because of compression / mass effect on the heart or great vessels.
3. There should be extracorporeal membrane oxygenation (ECMO) capabilities nearby with a perfusionist and anesthesia tech readily available to assist.

4. The cardiothoracic surgeon should be paying attention to induction. There should be close communication between the anesthesiologist and surgeon, so the surgeon knows whether to intervene with a rigid bronchoscope or prepare for ECMO cannulation.

(iv) The following equipment and staff members are readily available but are not present in the room unless the learner specifically asks for them:

1. Rigid bronchoscope
2. Perfusionist
3. ECMO / cardiac bypass machine and cannulation equipment
4. Crash cart with an automated external defibrillator (AED).

(v) The learner should try to maintain spontaneous ventilation in the patient. Possible methods may include a variation of inhaled induction with sevoflurane, and a titrated IV induction with ketamine and dexmedetomidine.

(vi) IF the learner does not try to maintain spontaneous ventilation and makes the patient apneic (example: non-judicious administration of narcotic or propofol, or administers muscle relaxant), then the learner will find the patient is impossible to mask ventilate in the supine position. The patient will gradually begin to desaturate. If the learner does not take steps to improve ventilation, then the patient will become bradycardic and hypotensive.

(vii) IF the learner does maintain spontaneous ventilation, they will still have some difficulty ventilating the patient. The patient will have limited chest rise and shallow tidal volumes.

(viii) Either way, the learner should take the following steps:

1. Attempt to reposition the patient – sitting upright, raising the head of the bed, turning right lateral decubitus or left lateral decubitus.
2. May try using higher peak pressures to mask ventilate or providing continuous positive airway pressure (CPAP) via circuit mask if spontaneously ventilating.
3. Notify the surgeon immediately and ask them to prepare for a rigid bronchoscope.
4. Proceed to intubate by direct laryngoscopy and try to manually bag via the ETT.

5. The learner who has administered muscle relaxant may request sugammadex, but this will not be available because the OR Pyxis is out of stock.
6. The learner may give epinephrine or a fluid bolus if the patient is bradycardic and hypotensive.

(ix) With repositioning, the learner will be able to ventilate the patient better. Vital signs will normalize.

(b) Phase 2: additional lines and monitors.

(i) The OR and anesthesia tech will be helpful in assisting with line placement.
(ii) The learner should proceed with placement of a second PIV and an arterial line.

(c) Phase 3: hemodynamic instability.

(i) Ventilation has improved with lateral positioning, but the surgeon reports that they cannot operate like this. The surgeon will ask if the learner can get the patient spontaneously ventilating again. The patient still has 0 twitches.
(ii) At this point, an OR runner will come in and provide sugammadex so that the learner can reverse the muscle relaxant, if this had been given during induction.
(iii) The surgeon will ask if now is a good time to try going supine.
(iv) The learner will slowly reposition the patient from lateral decubitus to supine. Tidal volumes will noticeably decrease for a given peak pressure. The learner may ask if the table can be adjusted – head of bed elevated or reverse Trendelenburg positioning.
(v) The surgeon will move quickly to perform the median sternotomy. There is minimal bleeding. They will move efficiently but carefully.
(vi) The patient will demonstrate hypotension and tachycardia. The learner may administer fluid boluses or inotropes / pressors to treat. The hemodynamics will improve and surgery will progress uneventfully.
(vii) The scenario will end here.

Scoring Rubric

Table 4.1 Scoring rubric for case scenario on Anterior Mediastinal Mass

Topic: Anterior Mediastinal Mass (Pediatric)			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Pre-operative evaluation			
History and physical exam	Ask about symptoms: Exercise tolerance, dyspnea, orthopnea, favored positions, fatigue, syncope.		
	Obtain set of baseline vital signs.		
	Inquire about other co-morbidities: Cardiac, pulmonary, neuromuscular disorders.		
	Perform physical exam: Auscultate bilateral breath sounds, observe for signs of superior vena cava (SVC) syndrome.		
Labs/imaging	Inquire about preoperative labs: Complete blood count (CBC), coagulation panel.		
	Inquire about preoperative echocardiogram: Contractility, diastolic function, compression of major vessels, compression of any chambers.		
	Inquires about oncology plan: Consideration for radiation therapy or steroids to shrink tumor prior to surgical resection.		
Room preparation			
Communication	Provides comfort and reassurance to anxious patient.		
	May perform debrief with the OR team discussing potential dangers and backup plans.		
Equipment/ staffing	Confirms cardiothoracic surgery and perfusionist are available to cannulate and crash onto bypass if needed.		
	Confirms ear/nose/throat (ENT) surgeon is available to perform rigid bronchoscopy in case unable to ventilate.		
	Positions patient in comfortable position to optimize ventilation.		
	Confirms in situ peripheral intravenous line (PIV) is functional.		
	Has difficult airway equipment in room: Various sized blades/endotracheal tubes (ETTs), video laryngoscope, fiberoptic bronchoscope, rigid bronchoscope, jet ventilator, cricothyroidotomy kit, crash cart with automated external defibrillator (AED) and pads on patient.		

Table 4.1 continued

Inability to ventilate			
Induction	May perform combination inhalational and intravenous induction.		
	Attempts to maintain spontaneous ventilation.		
	Administers intravenous (IV) agents with the goal of achieving general anesthesia, avoiding bronchospasm, laryngospasm, coughing/bucking, but maintaining spontaneous ventilation.		
	Possible IV agents include: Ketamine, dexmedetomidine, propofol, narcotics cautiously.		
	Avoids administering muscle relaxants.		
Ventilation	Calls for help.		
	Recognizes apnea or shallow tidal volumes.		
	Attempts to reposition patient: Sitting upright, raising head of bed, turning right or left lateral decubitus, prone.		
	May try using higher peak pressures to mask ventilate or providing continuous positive airway pressure (CPAP) if still spontaneously ventilating.		
	Notifies ENT surgeon and asks them to prepare rigid bronchoscopy.		
	Notifies cardiothoracic surgeon and asks to prepare for emergent cardiopulmonary bypass.		
	Proceeds to intubate and try to manually bag via endotracheal tube (ETT).		
	If administered muscle relaxant, may attempt to restore spontaneous ventilation by reversing neuromuscular blockade.		
Hemodynamic collapse			
Lines/drains/ airway	Establishes large bore PIV access.		
	Places arterial line.		
Intervention	Identifies hypotension and tachycardia.		
	Administers fluid bolus: Crystalloid 20 milliliters per kilogram (ml/kg).		
	May initiate inotropes or pressors.		
	Considers repositioning patient to alleviate mass compression on heart/great vessels.		

Summary of Clinical Teaching Points

Where do mediastinal masses come from? [1, 2]

- Primary mediastinal tumors
  - 54% anterior mediastinum
  - 20% middle mediastinum
  - 26% posterior mediastinum

- Most common causes of mediastinal tumors
  - T-cell lymphoblastic lymphoma / leukemia
  - Hodgkin lymphoma
  - Others: primary mediastinal B cell lymphoma, thymic tumors, germ cell tumors, rhabdomyosarcoma, Langerhans cell histiocytosis

Who is involved in the pre-operative evaluation?

- Emergency Department team
- Hematology-Oncology team
- Pulmonary Intensive Care Unit (PICU) team, even if PICU admission is not required, in case of a deterioration in clinical status
- Pediatric Surgery team
- Anesthesiology team
- Cardiology team, as patient may require a STAT echocardiogram
- All consultants must evaluate the patient in a timely fashion

When should you worry? [1, 2]

Table 4.2 Worrisome clinical signs and symptoms in anterior mediastinal mass in children

Critical Airway	Cardiac Compromise
Tracheal cross-sectional area <50% of predicted	Pericardial effusion causing tamponade
Peak expiratory flow rate in supine position <50% of predicted	Tumor impingement on any of the great vessels or cardiac chambers
Severe narrowing or complete occlusion of one or both mainstem bronchi	Signs of cardiac compromise: Hypoxemia, pulmonary edema, decreased cardiac output
Clinical findings of acute respiratory distress or impeding respiratory failure	Symptoms of cardiac compromise: Fatigue, shortness of breath, syncope, difficulty keeping up with peers, poor growth, loss of appetite
Signs of respiratory distress: Retractions, wheezing, stridor, hypoxemia, tachypnea, orthopnea, shortness of breath, anxiety	

What imaging and diagnostic studies should be done pre-operatively?

- Initial evaluation in the emergency department:
  - Chest radiograph (x-ray) to evaluate for the presence of a mediastinal mass

    Suspected leukemia
    Lymphadenopathy and suspected lymphoma
  - Labs: complete blood count (CBC) with differential, basic metabolic panel (BMP), uric acid, phosphate, lactate dehydrogenase (LDH), alpha fetoprotein (AFP), beta-human chorionic gonadotropin (HCG), disseminated intravascular coagulation (DIC) panel with coagulation studies

- All patients with evidence of mediastinal mass on chest x-ray should have a follow-up CT thorax in the ED to assess for tracheal size
- Consider ultrasound to evaluate for pericardial effusion, especially if there is evidence of cardiac compromise, for rapid preliminary evaluation
- All imaging must be read STAT
- Echocardiogram is mandatory

Why is the echocardiogram important?

- All patients with mediastinal masses require urgent / emergent echocardiogram
- What are you looking for?
  - Ventricular function
  - Pericardial effusion
  - Tamponade
  - Intravascular thrombi
  - Obstruction of great vessels

When is it safe to go to the operating room?

- CT thorax with contrast and ECHO are completed
- Ideally weekday morning when most staff available for back-up in case of intraoperative complications

What is the anesthetic management?

Table 4.3 Anesthetic management for biopsy versus resection of anterior mediastinal mass

Biopsy	Resection
Usually interventional radiology (IR)- or computed tomography (CT)-guided. Off-site at IR or CT suite versus in the main operating room (MOR) with portable IR/CT equipment	Done in the operating room
Maintain spontaneous ventilation	Maintain spontaneous ventilation
Perform under monitored anesthesia care (MAC)/sedation with local anesthetic	Requires general anesthetic
Supine position for bronchoscopy or mediastinoscopy	Lateral decubitus position for thoracotomy

What are your anesthetic goals?

Table 4.4 Anesthetic goals, challenges, and techniques for resection of anterior mediastinal mass

Anesthetic Challenges and Goals	Techniques
Maintain spontaneous ventilation	Titrated intravenous (IV) induction: Ketamine, dexmedetomidine, propofol infusion if anticipated difficulty airway or prolonged time to intubate Inhalational induction Minimize narcotics that would cause hypoventilation/apnea Consider regional anesthesia Whatever your medication of choice, use judiciously If muscle relaxation is needed, test small, short-acting dose and verify adequate ventilation and hemodynamics in that position with positive pressure ventilation (PPV)
Establish IV access quickly	Awake versus asleep peripheral intravenous line (PIV) Difficult IV equipment: Ultrasound machine, vein finder Experienced providers
Secure airway quickly	Difficult airway equipment Experienced laryngoscopist
Avoid collapse of mass onto critical structure that would lead to inability to ventilate and hemodynamic collapse	Reposition patient from supine position to alternatives that would alleviate compression from mediastinal mass: Lateral, prone, upright Rigid bronchoscope to elevate mass away from tracheo-bronchial tree and help restore ventilation and oxygenation Extracorporeal membrane oxygenation (ECMO) team on standby. Caution that even with team scrubbed in and pump primed, may take 15 minutes to establish cannulation and initiate ECMO. Hypoxic brain injury may occur during this time.

Why is spontaneous ventilation better than controlled ventilation for anesthetic management of anterior mediastinal mass?

Table 4.5 Comparison of spontaneous versus controlled ventilation for anesthetic management of anterior mediastinal mass

Spontaneous Ventilation = Negative Pressure Ventilation	Controlled Ventilation = Positive Pressure Ventilation
Decrease in intrathoracic pressure with inspiration	Positive pressure ventilation increases intrathoracic pressure
Less compressive effect of anterior mediastinal mass	Possible complete collapse of trachea, bronchi, or major vessels
Better at maintaining airway patency	Neuromuscular blockade increases collapse because lose tone of supporting muscles of chest wall, neck, and supraglottic airway

What happens under general anesthesia?

Table 4.6 Comparison benefits and dangers of general anesthesia for anesthetic management of anterior mediastinal mass

Benefits	Dangers
Establish secure airway – Potentially helps ventilate stenotic or compressed portions of trachea	Muscle relaxation from volatile anesthetic even without administration of paralytics
Comfort for patient – Lateral decubitus position for thoracotomy	Compression of tracheo-bronchial tree or cardiac structures
Ability to control ventilation in event of intraoperative hemodynamic collapse	Ventilation/perfusion (V/Q) mismatch, shunting, decreased lung volumes, inability to ventilate
Reduced risk of aspiration if esophageal compression is present	Hemodynamic collapse
	Pediatrics: More collapsible airway tissue More compliant chest wall

Preparation and Anticipation

- It is a good idea to do a team timeout before induction.
- Alert everyone to the fact that this patient may be difficult to ventilate, even if they have a normal airway exam and are easy to intubate, due to compression / mass effect of the anterior mediastinal mass on the tracheo-bronchial tree.
- Patient may become hemodynamically unstable and decrease their cardiac output because of compression and mass effect on the heart or great vessels.
- There should be ECMO capabilities nearby with a perfusionist and anesthesia tech readily available to assist.
- The cardiothoracic surgeon should be paying attention to induction. There should be close communication between the anesthesiologist and surgeon, so the surgeon knows whether to intervene with a rigid bronchoscope or prepare for ECMO cannulation.

What should you do if you cannot ventilate?

- Attempt to reposition the patient – sitting upright, raising the head of the bed, turning right lateral decubitus or left lateral decubitus.
- May try using higher peak pressures to mask ventilate or providing CPAP if spontaneously ventilating.
- Notify the surgeon immediately and ask them to prepare to perform rigid bronchoscopy.
- Proceed to intubate by direct laryngoscopy and try to manually bag via the ETT.

- Consider giving epinephrine or a fluid bolus 20 cc/kg to prevent the patient from becoming bradycardic and hypotensive due to mass compression and hypoxemia/hypercarbia.

What should you do if your patient becomes hypotensive?

- Know your pre-operative imaging: CT thorax and especially the ECHO
- Notify surgeons immediately so they can prepare to quickly open the chest and take the pressure of the anterior mediastinal mass off of the heart and great vessels
- Administer a fluid bolus to augment preload
- Consider inotropes (dopamine, epinephrine, etc.) to augment myocardial contractility
- Consider pressors to improve mean arterial pressure (MAP) and end-organ perfusion

In Summary

- When you hear "anterior mediastinal mass," PAUSE TO THINK.
- Remember your anatomy.
- Remember your physiology.
- Mobilize resources.
- Think of plans A, B, and C.

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Chapter 5
APNEA in Post-Anesthesia Care Unit (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Review the differential diagnoses for postoperative apnea.
2. Review signs and symptoms of elevated intracranial pressure (ICP).

Simulator Environment

1. Location: post-anesthesia care unit (PACU) of an adult hospital
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 x 20 Gauge (G) peripheral intravenous (PIV) line
   (c) Monitors: none on arrival in PACU
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, ketamine, hypertonic saline, mannitol.
4. Equipment available

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(a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
(b) Monitors: pulse oximeter, blood pressure cuff, 5-lead electrocardiogram (EKG).
(c) Lines: arterial line kit, central line kit, PIV kits
(d) Crash cart with defibrillator
(e) Paperwork: pre-operative anesthesia history and physical

Actors

1. PACU nurse
2. Neurologist

Scenario Development

1. Background
   (a) You are the anesthesiologist on call for the night and have just received sign-out about a stroke code: a 68-year-old woman with type 2 diabetes mellitus (T2DM), morbid obesity, severe obstructive sleep apnea (OSA) on continuous positive airway pressure (CPAP), hypertension (HTN), hyperlipidemia (HLD), and coronary artery disease (CAD) status post percutaneous coronary intervention (PCI) to the left anterior descending (LAD) artery 10 years ago was admitted for acute ischemic stroke and is now status post thrombectomy. Her initial stroke symptoms were weakness in her left lower extremity. The case was done under general anesthesia with endotracheal intubation and proceeded uneventfully. She was extubated about 20 minutes ago and then transported from the neuro-interventional radiology (Neuro IR) suite on the first floor to the operating room (OR) PACU on the second floor. The anesthesiologist who did the case already gave sign-out to the PACU nurse and is heading home for the day.
2. Phase 1: recognition of apnea and initiation of mask ventilation versus intubation
   (a) The patient is not yet on all the monitors in PACU. The learner will note that the patient does not look well – they are dusky, cyanotic all over; nonrespon-

sive; minimal chest rise. The patient is lying completely supine in bed, with the neck flexed, covered in blankets.

(b) The learner should take steps to identify and treat apnea as soon as possible.

(i) The learner should place all monitors on the patient.
(ii) The learner should place the patient on supplemental oxygen (face mask with Ambu Bag or Mapleson), provide assistive maneuvers such as chin lift and jaw thrust, and consider placing airway adjuncts (nasal trumpet, oral airway).
(iii) The learner should position the patient to optimize ventilation, including elevating the head of the bed and placing a shoulder roll.
(iv) The learner should recognize that the patient is apneic and deliver positive pressure breaths.
(v) The learner should decide whether to proceed with intubating the patient now or to mask ventilate and allow the patient time to resume breathing

3. Phase 2: intubation

(a) The learner should recognize that the patient is non-responsive and is making no respiratory effort.
(b) The patient will continue to desaturate.
(c) The patient will be difficult to mask ventilate due to morbidly obesity and severe OSA.
(d) The learner should make the decision to re-intubate in a timely fashion.
(e) The learner should optimize patient positioning (e.g. ramp). If the learner does not reposition the patient appropriately, they will be unable to intubate (grade 4 view on laryngoscopy).

4. Phase 3: etiology of apnea

(a) The learner should evaluate for causes of apnea:

(i) Check an arterial blood gas (ABG) to evaluate for possible anemia, electrolyte disturbances, severe acidosis whether respiratory or metabolic, hypoglycemia.
(ii) Inquire about recent medication administration in PACU.
(iii) Inquire about intraoperative course in the Neuro IR suite.
(iv) Inquire about past medical history and baseline mental status / neurologic exam on admission.
(v) Given the patient's recent stroke, the learner should examine the pupils and consider an intracranial bleed or elevated intracranial pressure.

Scoring Rubric

Table 5.1 Scoring rubric for case scenario on Apnea in the Post-Anesthesia Care Unit (PACU)

Topic: Apnea in PACU			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
POSTOPERATIVE APNEA			
Evaluation	Identifies that patient is apneic		
	Recognizes signs of apnea: Cyanosis, nonresponsive, minimal/absent chest rise		
	Removes blankets to better visualize patient's respiration		
	Places monitors immediately to assess current vital signs		
Management	Calls for help		
	Calls for advanced airway equipment (code bag, crash cart, Mapleson and face mask, airway adjuncts like oral airway and nasal trumpet)		
	Repositions patient to optimize ventilation: Elevates head of bed, places shoulder roll		
	Provides supplemental oxygen (simple face mask, mask with Mapleson or Ambu-bag)		
	Attempts to stimulate patient: Calling their name, sternal rub, jaw thrust, chin lift		
	Recognizes patient is still apneic		
	Initiates positive pressure ventilation via bag-mask ventilation in a timely fashion		
	Makes decision to reintubate patient		
	Reintubates patient in a timely fashion		
	Optimizes patient positioning for intubation		
	Hyperventilates patient to treat presumed hypercarbia		
Etiology	Surveys all monitors and vital signs to evaluate for possible hemodynamic instability		
	Takes history: Baseline neuro exam, major intraoperative events, recent medication administration in the post-anesthesia care unit (PACU)		
	Check labs, including pH, arterial carbon dioxide (PaCO2), glucose, and potassium, and hemoglobin (Hb)		
	Places arterial line for serial arterial blood gases (ABGs) or draws single stick ABG		
	Identifies abnormalities on ABG: Respiratory acidosis but normal glucose and electrolytes		
	Identifies severely elevated PaCO2 and suspects hypoventilation/apnea for long time frame (rise in end tidal carbon dioxide ($ETCO_2$) 2–3 mmHg/minute)		
	Performs basic neurologic exam		

Summary of Clinical Teaching Points

What are potential causes of apnea in the post-anesthesia care unit (PACU)?

Table 5.2 Causes of apnea in the post-anesthesia care unit (PACU)

System	Causes
Pulmonary	Upper airway obstruction Laryngospasm Bronchospasm Stridor
Neurologic	Stridor Elevated intracranial pressure (ICP) Seizure
Cardiovascular	Hypotension Myocardial ischemia Arrhythmia Pulmonary embolism
Gastrointestinal/hepatic	Aspiration
Renal/metabolic/endocrine	Electrolyte derangement: Hypoglycemia, hyperkalemia, hyponatremia Hypothermia Sepsis

How can a patient be "fine" and then suddenly dramatically desaturate? [1]

- Consider the rate of carbon dioxide (CO_2) accumulation
  - 6 mmHg in the first minute of apnea
  - 2–3 mmHg/minute thereafter
  - So if the $PaCO_2$ is 90 mmHg at the time of apnea evaluation and 40 mmHg is normal, then the patient accumulated 50 mmHg CO_2. This means the patient was probably apneic for >10–15 minutes before desaturation.
- Consider how busy the PACU is and the chances that someone will notice an apneic patient
  - Busy PACU, limited staffing
  - Patient covered in blankets and pillows, obstructing view of passersby
  - Suboptimal positioning
  - Noisy environment with lots of distractions
  - SpO_2 100% for minutes while CO_2 accumulates in the lungs…then acute oxygen desaturation dramatically
  - $P_AO_2 = FiO_2 (Patm – PH_2O) – (PaCO_2 / R)$
  - $P_AO_2 = 0.12 (760–47) – (90/0.8)$
  - $P_AO_2 = 149–112 = 37$

How do you decide whether to re-intubate the patient?

Table 5.3 Comparing pros and cons of re-intubating a patient for apnea in the post-anesthesia care unit

Pros	Cons
Frees your hands to do other things – Vascular access, medications, transport	Challenging to perform a neurologic exam
Ensures controlled ventilation and oxygenation	Longer time until patient gets extubated
Avoids aspiration risk if full-stomach	Social stigma – "You 'had to' reintubate"
Easier to resuscitate patient – Place lines, administer blood products, inotropes, and pressors	

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Chapter 6
Awake Tracheostomy (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Review indications for awake tracheostomy.
2. Discuss anesthetic management of awake tracheostomy.

Simulator Environment

1. Location: starts off on a regular floor in an adult hospital → will transition to operating room as case progresses
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 × 20 Gauge (G) peripheral intravenous (PIV) line
   (c) Monitors: NIBP cuff, 5-lead EKG, pulse ox
3. Medications available (in the operating room (OR)): normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam.
4. Equipment available (in OR):

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(a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
(b) Monitors: pulse oximeter, blood pressure cuff, 3-lead electrocardiogram (EKG).
(c) Lines: arterial line kit, central line kit, PIV kits
(d) Crash cart with defibrillator

Actors

1. Floor
   (a) Floor nurse
      (i) The floor nurse is busy trying to help place monitors and provide suction and towels to the patient.
   (b) Ear/Nose/Throat (ENT) surgery resident
      (i) The ENT resident is worried about the airway and asks the anesthesiologist to intubate the patient right away.
2. Operating room
   (a) Scrub tech
      (i) The scrub tech is hurriedly opening trays as fast as possible with such short notice.
   (b) Circulator RN
      (i) The circulator RN is hurriedly getting equipment as fast as possible and is focused on assisting the surgeons.
   (c) ENT attending
      (i) The ENT attending rushed in just in time and is moving quickly to do the awake tracheostomy.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist on call and carrying the code pager. You are called for a STAT intubation on the floor. Upon arrival, you see the ENT resident is there. The patient is a 65-year-old gentleman who is sitting upright in his bed, leaning forward. He is covered in bright red blood all over his face, neck, gown, and arms. Blood is shooting out from his mouth in a

pulsatile fashion, and he is holding a suction catheter inside his mouth. He appears pale and struggling to breathe on room air. Vital signs show oxygen saturation (SpO_2) in low 90s, mean arterial pressure (MAP) in the 60s, and elevated heart rate.

(b) The ENT resident and bedside nurse report that the patient had been stable all night and then when the RN checked on him this morning, he was bleeding heavily. He is post-operative day (POD) #2 from removal of a lesion on his hard palate. They think that he is having arterial bleeding from the hard palate at the surgical site.

(c) The patient is mentating well. He is surprisingly calm and cooperative.

2. Scenario development

(a) Phase 1: code blue on the floor

(i) The ENT resident wants the anesthesiologist to intubate immediately in the patient's room on the floor. They do not understand why the learner cannot just induce and intubate via direct laryngoscopy or Glidescope.

(ii) The learner should recognize that the patient needs to be taken to the operating room emergently for an awake tracheostomy. The learner should not attempt to intubate the patient on the floor.

(iii) If the learner attempts to intubate the patient at bedside on the floor, their view will be obscured and bloody and they will be unable to intubate, unable to ventilate. Blood will flood the oropharynx quickly due to the arterial bleed and they will be forced to perform an emergency trach.

(iv) The learner should mobilize resources quickly to prepare the operating room for an awake tracheostomy. This includes notifying the OR charge RN and communicating with the ENT attending. They should move quickly to transport the patient from floor to elevator to OR and recognize that the patient has no suction available during transport.

(b) Phase 2: awake tracheostomy in the operating room

(i) The learner should position the patient appropriately for awake trach while also enabling suctioning capabilities so the patient doesn't feel like they are drowning in blood in the oropharynx.

(ii) The learner should call in additional staffing to help place lines such as an arterial line, large bore PIVs or central line, and initiate blood transfusion.

(iii) The learner should assess the patient's mental status and provide verbal reassurance throughout. They should remain calm. If the patient is calm and cooperative, they can avoid providing any IV sedation. If the patient is anxious, they can consider cautiously administering IV sedation while avoiding apnea or upper airway obstruction: ketamine, dexmedetomidine, midazolam, narcotics such as fentanyl or remifentanil.

(iv) The awake trach will be performed quickly by the ENT team. Once the trach is secured, the patient can be induced and paralyzed. The stomach should be suctioned with an orogastric tube.

Scoring Rubric

Table 6.1 Scoring rubric for case scenario on Awake Tracheostomy

Topic: Awake Tracheostomy		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Out of or airway		
Assesses urgency of intubation		
Makes plan for whether to intubate the patient at bedside in floor unit or to take to the operating room (OR)		
Recognizes that patient's vital signs are stable and protective airway reflexes are intact		
Recognizes that it is safest for patient to be intubated in the OR		
Mobilizes resources: Calls OR, ear/nose/throat (ENT) surgeon, and back-up anesthesiologist to prepare the OR for awake tracheostomy		
Transports the patient in timely fashion from floor to OR		
Positions patient with head of bed elevated leaning forward to assist with bleeding management		
Brings emergency airway equipment en route		
Attempts to provide supplemental oxygen (nasal cannula, blow-by)		
Awake tracheostomy		
Positions the patient to optimize ventilation and suctioning capabilities		
May provide IV sedation to ease anxiety while preserving spontaneous ventilation (dexmedetomidine, ketamine, midazolam, fentanyl)		
Counsels patient throughout the surgery		
Establishes large bore intravenous access (peripheral intravenous lines, central line)		
Places arterial line		
Checks ABG to evaluate possible anemia		
Transfuses blood products in balanced ratio appropriate to degree of anemia and bleeding		
After insertion of tracheostomy tube, confirms end-tidal carbon dioxide ($ETCO_2$)/capnogram		

Summary of Clinical Teaching Points

When should you move a patient from an out-of-operating room setting to the operating room for intubation?

- Difficult airway anticipated
  - As the anesthesiologist asked to intubate, you are ultimately the one to decide.
- Other considerations
  - Only you know your skills and what you are capable of.
  - It's not about pride. It's about keeping the patient safe.
  - If you lose control of the airway (cannot intubate, cannot ventilate), are you prepared to do an emergency bedside cricothyroidotomy?
  - How long will it take to get a hold of a surgeon (Ear/Nose/Throat, Trauma, General surgery) to assist with an emergency surgical airway?
  - How long will it take to prepare the operating room?

How to Mobilize Resources

- Communicate
  - Operating Room charge nurse
  - Any other anesthesiologists in-house who could be available to help you

    Main Operating Room call
    Obstetric Anesthesia call
    Anesthesia and Critical Care Medicine call
    Anesthesia tech
    Any surgeon capable of performing a fast tracheostomy

    - Ear / Nose /Throat Surgeon
    - Trauma Surgeon
    - General Surgeon
- Prepare for emergency transport
  - Code bag
  - Unfortunately no transport suction, so transport quickly
  - Cricothyroidotomy kit in case patient decompensates during transport and cannot intubate from above
- Prepare for the operating room
  - Sedation: ketamine, dexmedetomidine, midazolam, fentanyl
  - Hemodynamics: pressors, inotropes, crystalloids, colloids, packed red blood cells
  - Lines: arterial line, central line, large bore peripheral IV (PIV) access
  - Standard difficult airway equipment

Indications for Awake Tracheostomy [1–3]

Table 6.2 Indications for an awake airway intervention

Indications for Any Awake Airway Intervention	Indications for Tracheostomy
Difficult airway: Known or anticipated, where cannot intubate and cannot ventilate	ENT procedure where postoperative airway obstruction is anticipated
Examples: Craniofacial abnormalities Radiation to the neck: Woody texture, stiff, immobile, poor compliance Large mass – Malignancy, abscess, hemangioma Mass at a dangerous location (e.g. obstructing the glottic opening) Bleeding	Obstruction of upper airway secondary to infection, trauma, tumor
	Craniofacial abnormality
	Prolonged need for ventilatory support (neuromuscular disease, pulmonary disease)
	Vocal cord paralysis

Should you administer sedation for an awake tracheostomy? [1–3]

- Truly awake = no sedation at all
  - Hard to achieve: often done in an emergent setting; anxious, hypoxic patient; anxious staff; anxious environment
  - Requires cooperative patient and attentive anesthesiologist providing verbal reassurance step-by-step
  - Requires good local anesthesia by surgeon
  - Recommend restraining patient's arms and assistant holding head
  - Be prepared to administer propofol and paralytic as soon as the tracheotomy tube is in the trachea, will stimulate patient to cough and buck
- Mild sedation
  - Normal response to verbal or light tactile stimuli, minimal effect on airway compromise
  - Commonly used medications:

    Dexmedetomidine – reserves spontaneous ventilation, can cause upper airway obstruction/collapse
    Ketamine – generally preserves spontaneous ventilation, patient might not follow commands, dissociative state (difficulty distinguishing hallucinations versus reality)
    Midazolam – anxiolytic, can lead to disinhibition, resulting in uncooperative patient who has difficulty remaining still
    Fentanyl – analgesia, can cause apnea

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Chapter 7
Brain Code (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss anesthetic management of stroke code.
2. Describe signs and symptoms of elevated intracranial pressure.
3. Discuss acute management of elevated intracranial pressure.

Simulator Environment

1. Location: interventional radiology suite of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 x 20 Gauge (G) peripheral intravenous (PIV) line, radial arterial line, foley catheter
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, calcium chloride, hypertonic saline, mannitol.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction, fiberoptic bronchoscope, video laryngoscope.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator
   (e) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy opening trays.
2. Circulator nurse
   (a) The nurse is busy charting.
3. Neuro-interventional radiologist
   (a) The neuro-interventional radiology (Neuro-IR) team is focused on locating and removing the clot.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist taking care of a 70-year-old man with poorly controlled type 2 diabetes mellitus (T2DM) and severe gastroesophageal reflux disease (GERD). He was found down in the parking lot of a grocery store and on exam was found to have dysarthria, dysphagia, facial droop, and hemiparesis. Computed tomography (CT) scan of the head confirmed acute ischemic middle cerebral artery (MCA) stroke.
   (b) He is currently in the interventional radiology suite undergoing diagnostic cerebral angiogram and clot removal under monitored anesthesia care (MAC)/sedation with propofol infusion for maintenance of anesthesia.

(c) Medications: insulin, metformin, gabapentin.
(d) Preoperative labs: potassium (K) 4.9, hemoglobin (Hb) 11.5, bicarbonate (HCO_3) 30.

2. Phase 1: coughing, vomiting and nonresponsiveness

(a) The patient is initially doing well, calm, breathing spontaneously on simple face mask. The surgeons are advancing their catheter towards the clot when suddenly the patient starts coughing and moving. The patient is unable to remain still despite verbal instructions from the staff. He then turns his head and throws up. He becomes nonresponsive, hypoventilating, and is no longer following commands.
(b) The learner should move to the head of the bed and recognize the hypoventilation and acute change in neurologic status. The learner should move to intubate as soon as possible to protect against aspiration.

3. Phase 2: intracranial bleed leading to elevated intracranial pressure

(a) The blood pressure will acutely increase to systolic blood pressure (SBP) 190 s and the heart rate will slow down to the 40s–50s. The surgeon will now report that on angiogram, there was an accidental rupture of a major cerebral artery that must have occurred while the patient was coughing.
(b) The learner should recognize an acute intracranial bleed now resulting in elevated intracranial pressure, and should activate a brain code. They should recommend the following steps:

(i) The surgeon will remove the catheter and hold pressure at the groin site.
(ii) Brain code will be activated to alert pharmacy and neurology.
(iii) Administer mannitol or hypertonic saline loading dose/infusion.
(iv) Hyperventilate the patient.
(v) Alert the operating room and prepare for possible surgical decompression – Burr holes, craniotomy for clot evacuation.
(vi) Ask the surgeons to consider emergent external ventricular drain (EVD) placement for intracranial pressure (ICP) treatment and monitoring.
(vii) Elevate head of bed.
(viii) Manage hemodynamics: maintain goal cerebral perfusion pressure (CPP) >60 while also controlling hypertension to avoid hematoma expansion.

Scoring Rubric

Table 7.1 Scoring rubric for case scenario on Brain Code

Topic: Brain Code		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Aspiration		
Recognizes acute change in mental status		
Relocates self to head of bed to assess patient's mental status and respiratory status		
Suctions oropharynx		
Administers supplemental oxygen: Switches simple face mask to circuit mask for better seal		
Intubates patient in a timely fashion to protect against aspiration		
Elevated intracranial pressure		
Identifies hemodynamic instability: Hypertension and bradycardia that occurred acutely		
Recognizes hemodynamic signs of intracranial hypertension		
Calls for help		
Activates brain code to alert pharmacy and neurosurgery		
Hyperventilates the patient with 100% fraction of inspired oxygen (FiO_2)		
Administers mannitol or hypertonic saline		
Establishes large-bore peripheral intravenous (PIV) access		
Places arterial line		
Orders PRBCs to be crossmatched		
Requests the operating room be alerted and prepared for possible surgical decompression		
Elevates the head of bed when possible		
Maintains adequate cerebral perfusion pressure		
Weighs risk of hypertension in causing further hematoma expansion		
Discusses with surgeon possible emergent decompressive procedures to be done prior to the operating room (OR): External ventricular drain (EVD) placement, Burr holes		

Summary of Clinical Teaching Points

What are the pros and cons of doing a diagnostic cerebral angiogram and intervention under general anesthesia with an endotracheal tube (GETA) versus monitored anesthesia care (MAC)/sedation?

Table 7.2 Comparison of pros and cons of general anesthesia versus sedation for stroke intervention

	General Anesthesia and Endotracheal Intubation (GETA)	Monitored Anesthesia Care (MAC)/Sedation
Pros	Airway protection High aspiration risk (especially if neurologic deficits include dysphagia, dysarthria, facial droop, depressed mental status) Avoid intraoperative emergency conversion to a general anesthetic if complication occurs Avoids pain, anxiety, agitation Avoids patient movement that could lead to unintentional vessel perforation / dissection	Enables providers to track changes in neurologic exam in timely fashion. Enables early detection of exacerbated, new, or resolved neurologic deficits Improves early detection of iatrogenic intracerebral hemorrhage
Cons	Unable to track changes in mental status or neurologic exam May cause hemodynamic instability especially with induction May involve ventilation-associated complications Delays time to extubation and post-operative repeat neurological exam	Sedation may exacerbate altered mental status due to stroke, increasing aspiration risk with an unprotected airway If patient becomes disoriented or disinhibited, patient may move and disrupt surgical field

What are the signs and symptoms of intracranial hypertension? [1–4]

- Presentation
  - Headache
  - Decreased consciousness
  - Vomiting
  - Cushing triad: hypertension, bradycardia, respiratory arrest
  - Dilated pupil on ipsilateral side of hemorrhage
  - Cranial nerve palsies III, IV, VI – double vision, ptosis
- When to call a brain code
  - Signs of herniation
  - Intracranial pressure >20 cm H_2O for >3 minutes

How do you manage intracranial hypertension? [1–4]

- Activate hospital Brain Code to alert Pharmacy and Neurology
- Administer mannitol or hypertonic saline loading dose or infusion.
- Hyperventilate the patient.
- Operative management
  - Alert the operating room and prepare for possible surgical decompression – Burr holes, craniotomy for clot evacuation.

  - Ask the surgeons to consider emergent external ventricular drain (EVD) placement for intracranial pressure (ICP) treatment and monitoring.

- Elevated head of bed.
- Manage hemodynamics: goal cerebral perfusion pressure (CPP) >60 mmHg, intracranial pressure (ICP) <20 mmHg.
  - If someone is herniating, do not use antihypertensives to lower blood pressure – generally need a higher mean arterial pressure (MAP) in the setting of higher ICP to maintain CPP.
  - Also avoid overshooting MAP, which will skyrocket cerebral blood flow (CBF) and exacerbate ICP.
- Ensure adequate oxygenation.
- Consider antiepileptics.
- Consider antipyretics.
- Avoid hyperglycemia.

How do you manage intracranial hemorrhage? [1–4]

Table 7.3 Comparison of hypertonic saline versus mannitol for management of intracranial hypertension

	Hypertonic Saline (3% NaCl)	Mannitol
Indications	Cerebral edema Elevated intracranial pressure Hyponatremic seizures	Cerebral edema Elevated intracranial pressure
Mechanism of action	Increases serum sodium Creates osmotic gradient Induces shift of fluid from intracellular to extracelluar space Increases effective circulating volume Osmolarity of 1026 mEq/L	Increases plasma osmolarity and draws water from brain cells into vasculature leading to diuresis Osmolarity of 1098 mEq/L
Dosing	Cerebral edema: 3–5 cc/kg over 10–20 minutes 3 cc/kg will increase serum sodium by 2–3 mmol/L, maybe greater if large diuresis occurs	Start with 0.5–1 gram/kg, maximum 2 grams/kg Give slowly over 30 minutes Too fast: Dramatic electrolyte derangements Too slow: Equilibrates, doesn't change plasma osmolarity to drive diuresis

Table 7.3 (continued)

	Hypertonic Saline (3% NaCl)	Mannitol
Nuances	As effective as mannitol for treatment of elevated ICP Less "rebound" ICP No obligatory osmotic diuresis (plasma volume is preserved/expanded) Reno-protective Monitoring osmolality: Use serum sodium	May be nephrotoxic More readily available in the operating room Monitoring osmolality: Infer osmolar gap Metabolic derangements: Metabolic acidosis because dilution of serum bicarbonate; hypokalemia or hyperkalemia; dilutional hyponatremia Caution in patients who cannot tolerate significant increases in intravascular volume (e.g. congestive heart failure). May need to provide inotropic support or preempt with furosemide to offload increased venous return to heart Caution in patients who are already hypovolemic. Goal is to create a gradient, not to dehydrate the patient

- Immediate control of blood pressure within 10 minutes
  - Goal is to prevent hematoma from expanding
  - Goal systolic blood pressure (SPB) <150 mmHg
  - Antihypertensives: nicardipine, labetalol, hydralazine
- Immediate reversal of coagulopathy

How do you decide whether to use hypertonic saline or mannitol to treat intracranial hypertension? [1–4]

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Chapter 8
Bronchospasm (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss causes of apnea post-extubation.
2. Discuss signs and symptoms of bronchospasm.
3. Discuss intraoperative management of bronchospasm.

Simulator Environment

1. Location: operating room of a children's hospital.
2. Manikin setup:
   (a) Age: infant
   (b) Lines: 1 x 24 Gauge (G) peripheral intravenous line (PIV).
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 3-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide ($ETCO_2$).
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam.
4. Equipment available

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(a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
(b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG, radial arterial line.
(c) Lines: arterial line kit, central line kit, PIV kits
(d) Crash cart with defibrillator
(e) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy counting instruments and tidying up traps.
2. Operating room (OR) nurse
   (a) The nurse is busy finishing up charting and bringing in the gurney.
3. Surgeon
   (a) The surgeon is busy sitting at the computer and dictating the operative note.

Scenario Development

1. Background
   (a) You are the anesthesiologist finishing up a case of a healthy infant who has just finished undergoing inguinal hernia repair by general anesthesia with an endotracheal tube.
2. Phase 1: absent $ETCO_2$ and identification of bronchospasm.
   (a) The learner will be preparing to emerge and extubate the patient, but not yet have extubated. The OR nurse will lift up the baby's legs and wipe the baby's bottom with a cold diaper wipe.
   (b) The $ETCO_2$ capnogram will subsequently become completely flat, with zero $ETCO_2$. The patient will gradually start to desaturate.

(c) The learner should take the following measures to ensure appropriate oxygenation/ventilation and establish a differential diagnosis:

(i) Ensure they are on 100% fraction of inspired oxygen (FiO_2).
(ii) Manually bag the patient.
(iii) Check the circuit and ETT.
(iv) Consider direct laryngoscopy to rule out unintentional extubation.
(v) Consider passing a soft suction catheter down the ETT to rule out clot, obstruction, kinking, or mucus plugging.
(vi) Auscultate for bilateral breath sounds (in this case, the bronchospasm will be so severe that there is completely absent breath sounds).
(vii) Observe chest wall movement with manual bagging.

3. Phase 2: treatment of bronchospasm.

(a) The learner should recognize severe bronchospasm and treat it as soon as possible:

(i) Epinephrine intravenously (IV) first-line.
(ii) The learner may try to administer albuterol via the circuit, but should recognize that in such severe bronchospasm, it is unlikely that the albuterol will reach distal airways.
(iii) 100% FiO2.
(iv) Deepen the anesthetic with a volatile agent that will not irritate the airways (e.g. sevoflurane preferred instead of desflurane).

(b) If the learner does not recognize/treat the bronchospasm in a timely fashion, the patient will continue to desaturate and will go into cardiac arrest (bradycardia, hypotension), resulting in initiation of Pediatric Advanced Life Support (PALS).
(c) With initiation of treatment of bronchospasm, $ETCO_2$ will start to return with upslanted capnograms. Breath sounds will be appreciated, with bilateral expiratory wheezing.
(d) The learner will need to decide whether to try to extubate the patient and continue treatment via albuterol nebulize in the post-anesthesia care unit (PACU), or whether to remain intubated and continue to observe in the OR versus go to the pediatric intensive care unit (PICU) intubated.

Scoring Rubric

Table 8.1 Scoring rubric for case scenario on Pediatric Bronchospasm

Topic: Pediatric Bronchospasm			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Severe bronchospasm			
Evaluation	Identifies lack of ventilation		
	Identifies abnormal capnogram waveform		
	Places the patient on 100% fraction of inspired oxygen (FiO_2)		
	Manually bags the patient to assess compliance		
	Checks the ventilator circuit		
	Checks the endotracheal tube (ETT) for patency by palpation or passage of soft suction catheter or fiberoptic bronchoscopy		
	May call for fiberoptic bronchoscope		
	May perform direct laryngoscopy to rule out unintentional extubation		
	Rules out ETT clot, obstruction, kinking, or mucus plugging		
	Auscultates for bilateral breath sounds		
	Recognizes patient is still intubated but has absent breath sounds		
Management	Identifies severe bronchospasm		
	May attempt to administer albuterol via ETT		
	Recognizes that albuterol via ETT is unlikely to reach distal airways		
	Administers epinephrine intravenously (IV) 0.1–1 microgram (mcg)/kilogram (kg)		
	Deepens the anesthetic with non-irritating volatile agent (e.g. sevoflurane not desflurane)		
	Identifies signs of resolving bronchospasm: Return of end-tidal carbon dioxide ($ETCO_2$), upslanted capnogram, return of breath sounds with bilateral expiratory wheezing		

Table 8.1 (continued)

Cardiac arrest			
	Identifies hypotension and bradycardia		
	Recognizes that hypotension/bradycardia are due to inadequate ventilation/oxygenation		
	Administers fluid bolus of crystalloid 20 milliliters (ml)/kilogram (kg)		
	Administers inotropic agent to support blood pressure and heart rate: Epinephrine 0.1–1 mcg/kg, ephedrine 0.1 milligrams (mg)/kilogram (kg)		
	Initiates pediatric advanced life support (PALS) if patient's heart rate (HR) < 60 beats per minute (bpm): Chest compressions, epinephrine 10 mcg/kg		
Disposition			
	Establish criteria for deciding whether it is safe to extubate the patient in the operating room (OR): Improvement in breath sounds, improvement in tidal volumes, improvement in peak pressure, improvement in capnogram, period of observation in OR		
	If extubating in the OR, order albuterol nebulizer treatment to be administered in post-anesthesia care unit (PACU)		
	If extubating in the OR, establish criteria for safe discharge to home (live near hospital, reliable parents to observe child's breathing, criteria for calling emergency medical services)		
	If remaining intubated, call pediatric intensive care unit (PICU) and sign out indications for admission		

Summary of Clinical Teaching Points

What are possible post-extubation complications in pediatric patients?

Table 8.2 Common causes of pediatric post-extubation complications

Event	Cause	Prevention and Treatment
Upper airway obstruction	Excessive narcotics Obstructive sleep apnea	Larger adolescent: Reposition to head of bed elevated Smaller: Reposition to lateral decubitus position with head extension
Laryngospasm	Deep extubation / laryngeal mask airway (LMA) removal Secretions Stage 2 emergence/extubation	Ensure adequate ventilation prior to leaving the operating room Minimize secretions by thoroughly suctioning Minimize head/neck manipulation post-extubation
Stridor	Airway edema Traumatic intubation Nerve injury	Early recognition Intravenous dexamethasone Racemic epinephrine Head of bed elevation
Bronchospasm	Recent upper respiratory infection Known asthma	Albuterol nebulizer Intravenous epinephrine

What is bronchospasm? [1, 2]

- Sudden constriction of the muscles in the walls of the bronchioles
- Caused by release of inflammatory substances from mast cells or basophils
- Immediate hypersensitivity reaction
  - Anaphylaxis – IgE mediated
  - Anaphylactoid reaction
- Non-allergic reaction
  - Mechanical factors: intubation-induced
  - Pharmacologic: histamine-releasing medications
- Risk factors
  - Smokers
  - Chronic obstruction pulmonary disease (COPD)
  - Asthma
  - Recent upper respiratory infection or pneumonia
  - Light anesthesia
  - Endotracheal intubation

How do you troubleshoot hypoxemia?

- Ensure patient is on 100% fraction of inspired oxygen (FiO_2).
- Manually bag the patient to assess compliance.
- Check the ventilator circuit and endotracheal tube for signs of obstruction or disconnect.

- Note your peak pressure and plateau pressure on the ventilator.
- If on pressure-controlled ventilation (commonly done in pediatrics), check for changes in tidal volume for a given set peak inspiratory pressure.
- Consider direct laryngoscopy to rule out unintentional extubation.
- Consider passing a soft suction catheter down the endotracheal tube to rule out clot, obstruction, kinking, or mucus plugging.
- Auscultate for bilateral breath sounds.
- Observe chest wall movement with manual bagging.

What are signs of bronchospasm? [1, 2]

- Decreased end-tidal carbon dioxide ($ETCO_2$) – in severe cases of bronchospasm, may have completely flat or absent capnogram tracing.
- Upslanted capnogram – indicative of prolonged expiratory phase.
- Increased peak airway pressure
- Hypoxemia, oxygen desaturation
- Auscultation
  - Wheezing, inspiratory and/or expiratory
  - Diminished breath sounds
  - May have absent breath sounds in severe cases

How do you treat bronchospasm? [1, 2]

- Epinephrine intravenously (IV)
  - May start with a small bolus, such as 0.1 micrograms (mg)/kilogram (kg)
  - May need to start an epinephrine infusion if severe bronchospasm requiring repeated epinephrine boluses – consider a starting dose of 0.02 mcg/kg/minute and uptitrating as needed. May need to establish central venous access.
- Albuterol
  - Be generous: can administer 10 puffs at a time, coordinated with a positive pressure breath to ensure distribution to tracheobronchial tree.
  - In severe cases of bronchospasm, it is unlikely that the albuterol will reach the distal airways. Consider giving a systemic-reaching medication such as epinephrine IV.
- 100% FiO2
- Deepen the inhaled and intravenous anesthetic
  - Use volatile inhaled agents that will not irritate the airways (e.g. sevoflurane instead of desflurane)
  - Propofol
  - Ketamine
  - Lidocaine

How can a patient go into cardiac arrest from severe bronchospasm?

Table 8.3 Cardiac consequences of severe bronchospasm

Inadequate Oxygenation and Ventilation	High Intra-Thoracic Pressures
Hypoxemia, hypercarbia, acidosis	Decreased venous return → decreased preload → decreased stroke volume → decreased cardiac output → decreased coronary perfusion pressure
Poorly contractile myocardium	Increased pulmonary artery pressure → right heart strain → septal bowing into the left ventricle → decreased cardiac output → decreased coronary perfusion pressure → decreased contractility → decreased cardiac output
Decreased cardiac output	
Decreased coronary perfusion pressure	
Decreased oxygenation of the blood that is delivered to the myocardium	
Children: Bradycardia, hypotension, cardiac arrest → pediatric advanced life support (PALS)	
Adults: Myocardial ischemia, hypotension, arrhythmias, arrest → advanced cardiac life support (ACLS)	

How do you decide whether to extubate in the operating room or to remain intubated? [1, 2]

Table 8.4 Comparison of pros and cons of awake versus deep extubation and extubation in the operating room versus in the intensive care unit

Option	Pros	Cons
Deep extubation in the operating room	Avoids exacerbating bronchospasm during emergence / stage 2	Some degree of muscle weakness from volatile anesthetic in a patient who may need maximal respiratory effort, as much muscle strength as possible
Awake extubation in operating room	Ensures all volatile anesthetic is ventilated off → maximize muscle strength to give patient best chance of ventilating	Delayed time to ventilate off the volatile anesthetic, especially with delayed expiration
Extubate and go to the post-anesthesia care unit (PACU)	Gives patient opportunity to spontaneously ventilate and avoid admission to intensive care unit (ICU)	Risk of reintubation – May be traumatic/difficult in an emergent setting Risk of failure to respond to albuterol nebulizer in PACU Requires close monitoring – Possibly understaffed PACU, limited physician availability in a crisis should the patient decompensate
Remain intubated and go to ICU	Gives time for airways to calm down and bronchospasm to resolve Enables controlled ventilation to prevent hypoxemia and hypercarbia Enables continued administration of medications to alleviate bronchospasm, such as epinephrine infusion and albuterol nebulizers via the endotracheal tube	May have limited resources depending on setting – Ambulatory surgical center versus tertiary care hospital with ICU capabilities Unplanned admission

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Chapter 9
Burn Resuscitation (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss burn management in the acute setting, including indications for intubation.
2. Review crisis management strategies, including triaging patients, allocating resources, and being an effective leader and communicator.

Simulator Environment

1. Location: trauma bay of an adult hospital.
2. Manikin setup:
   (a) Age: small child
   (b) Lines: 1 x 22 gauge (G) peripheral intravenous (PIV) line in the antecubital (AC) fossa.
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter.

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3. Medications available: normal saline, albumin, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam.
4. Equipment available
   (a) Airway equipment: transport ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG, radial arterial line.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator

Actors

1. Multiple surgical intensive care unit (SICU) and trauma nurses
2. Trauma surgeons
3. Emergency room physicians

Scenario Development

8. Background
   (a) You are the anesthesiologist on call. You are called STAT to the trauma bay for a house fire.
9. Phase 1: triage and division of resources
   (a) The patient is a 5-year-old girl, normal body mass index (BMI), who appears healthy and well-developed. She is lying completely still in bed, breathing shallow on room air. She is covered in soot including around her hair, nose, and mouth. Her eyebrows and hair are singed.
      (i) She does not flinch when a PIV is placed and does not talk when spoken to.

(ii) There is bilateral wheezing on auscultation.
(iii) Her vital signs are oxygen saturation (SpO_2) 88% on room air, heart rate (HR) 140, blood pressure (BP) 110/80.

(b) The learner should assign roles: managing the airway, establishing vascular access.

10. Phase 3: airway management

(a) The learner should recognize signs of inhalational injury in the child: singed hair, soot around face, hypoxemia, and bilateral wheezing.
(b) The learner should move to intubate the child as quickly as possible.
(c) After intubation, the SpO2 will improve to the low 90s despite high fraction of inspired oxygen (FiO_2). The learner should recognize hypoxemia and attempt to treat and diagnose.

(iv) The learner may administer albuterol nebulizer and/or epinephrine IV to treat the bronchospasm.
(v) The learner may use a soft suction catheter to suction the endotracheal tube for possible soot or mucus.
(vi) The learner may perform a flexible fiberoptic bronchoscopy to do a lavage and better suction for soot or mucus.
(vii) After the above interventions, the bronchospasm will resolve and the saturation will improve.

11. Phase 4: circulation resuscitation

(a) After securing the airways, the learner should establish larger bore vascular including arterial line and central line.
(b) The learner should send rainbow labs (complete blood count (CBC), coagulation panel, basic metabolic panel (BMP)) and type and cross blood products (packed red blood cells (PRBCs), fresh frozen plasma (FFP)).
(c) The learner should begin fluid resuscitating the patient following the Parkland formula.

Scoring Rubric

Table 9.1 Scoring rubric for case scenario on House Fire

Topic: House Fire (Pediatric)		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Initial survey		
Identify team leaders		
Assign roles and responsibilities appropriate to skills		
ABCs: Evaluates airway, breathing, and circulation		
Establishes intravenous (IV) access		
Performs initial trauma survey after ABCs of airway/breathing/circulation, the D/E of disability and exposure		
Obtains labs: Complete blood count (CBC), basic metabolic panel (BMP), coagulation studies		
Obtains chest radiograph (CXR) and/or computed tomography (CT) scan of the head		
Divides staff into 3 teams, 1 per patient		
Surveys burn extent and severity		
Airway/breathing		
Identifies high risk of airway edema and lung injury due to smoke inhalation		
Proceeds with timely intubation		
Prepares difficult airway equipment and smaller endotracheal tubes (ETTs) in case of airway edema and difficult mask ventilation/difficult intubation		
Performs rapid sequence induction		
Circulation		
Establishes central line access		
Establishes arterial line access		
Crossmatches blood products: Packed red blood cells (PRBCs), fresh frozen plasma (FFP), +/− platelets		
Fluid resuscitates patient using parkland formula: 4 milliliters (mL)/kilogram (kg) bolus. Give half of the volume in first 8 hours and second half of the volume in the next 16 hours		
Starts maintenance fluids: 4/2/1 milliliters (ml)/kilogram (kg)/hour (hr)		

Summary of Clinical Teaching Points

Table 9.2 Head-to-toe systemic assessment of a trauma/burn patient

Systemic	Tasks
Airway	Determine need for intubation Cervical spine protection
Breathing	Suspicion for inhalation injury and rapid airway compromise Suspicion for carbon monoxide poisoning
Circulation	Fluid replacement
Disability	Suspicion for compartment syndrome Mental status may be altered due to hypoxia, hypercarbia, hypovolemia
Exposure	Remove all clothing and jewelry Evaluate for heat loss and hypothermia Assess severity and extent of burn
Fluids	Fluid resuscitation

How do you perform a systemic head-to-toe assessment of a trauma/burn patient?.

How do you perform crisis management?

- Determine your resources available, including personnel and equipment:
  - Advanced airway skills.
  - Vascular access skills.
  - Specifically, pediatrics experience.
- Divide and conquer, especially in situations with multiple trauma patients.
  - Decide which patient is the most unstable or most critically ill.
  - Assign appropriate personnel with experience to advanced airway interventions: anesthesiologist, emergency medicine physician, trauma surgeon.
  - Assign appropriate personnel with experience in pediatric vascular access to establish venous access.
  - Identify those who have pediatrics experience.
  - Assuming the patient is stable, the trauma and burn surgeons will eventually need to relocate the patient from the trauma bay to the burn intensive care unit. Start mobilizing staff and equipment in anticipation of the patient's arrival.
  - For those staff with limited/no skills, tell them to get out of the way.

What do you need to know about the burn history? [1–3]

- What was the mechanism of the burn?
  - Type of burn agent: scald, flame, electrical, chemical.
  - First aid administered already.
  - Risk of concomitant injuries: fall from height, explosion, motor vehicle collision.
  - Risk of inhalational injury, especially if there was a flame in an enclosed space.
- What was the timing of the burn?
  - When did the injury occur?
  - How long was the patient exposed to the source?
  - When was fluid resuscitation begun?
- Is there suspicion for non-accidental trauma, especially in a child?
- Standard history from any trauma patient:
  - Past medical history
  - Prior surgeries
  - Medications
  - Allergies
  - Vaccinations
  - Developmental milestones
  - Social history (smoking, substance use)

How do you evaluate the airway in a burn patient? [1–3]

- Stabilize the cervical spine as indicated.
- Be wary of inhalation of hot gases: these can cause a burn injury above the vocal cords, leading to the development of edema over the next few hours, especially with the initiation of fluid resuscitation.
- Keep in mind that a patient may have a patent airway on arrival, which can swell and become an obstructed airway soon after.
- Directly inspect the oropharynx.
- Look for signs of inhalation injury:
  - History; flame burns, burns in an enclosed space.
  - Full thickness or deep dermal burns to the face, neck, or upper torso.
  - Singed nasal hair.
  - Carbonaceous sputum or carbon particles in the oropharynx.
- Evaluate for indications that the patient need to be intubated:
  - Erythema or swelling of the oropharynx on direct visualization.
  - Changes in voice (hoarseness, harsh cough).
  - Stridor.
  - Tachypnea.
  - Dyspnea.
  - Desaturation or increasing oxygen requirements.

How do you evaluate breathing in a burn patient? [1–3]

- Provide supplemental oxygen (example: 100% oxygen via humidified non-rebreather).
- Evaluate for mechanical restriction of breathing. Risk factors include deep dermal or full thickness circumferential burns of the abdomen and/or chest. These may require escharotomies upon arrival to the burn intensive care unit.
- For patients with blast injury, assess for penetrating injury to the thorax that may cause pneumothorax, hemothorax, or lung contusions.
- For patients who suffered smoke inhalation, consider consequences of direct irritants on the lungs and trachea-bronchial tree: bronchospasm, inflammation, bronchorrhea, impaired ciliary action, atelectasis, pneumonitis, eventual pneumonia.
- Especially for burn patients who suffered smoke inhalation, have a high suspicion for carboxy-hemoglobinemia. Treat with 100% fraction of inspired oxygen.

What are the symptoms associated with carboxy-hemoglobinemia (COHb)? [1–3]

- 0–10% COHb: minimal (normal level in heavy smokers).
- 10–20% COHb: nausea, headache.
- 20–30% COHb: drowsiness, lethargy.
- 30–40% COHb: confusion, agitation.
- 40–50% COHb: coma, respiratory depression.
- >50% COHb: death.

How do you evaluate burn severity? [1–3]

- Calculate the total body surface area (TBSA) of the burn. Be clear and concise.
- A common tool to help calculate burn surface area is to use the Wallace Rule of 9's:
  - In an adult:

    Head (front and back) is 9% of TBSA
    Back is 18%
    Chest is 18%
    Right arm is 9%
    Left arm is 9%
    Perineum is 1%
    Right leg is 18%
    Left leg is 18%

  - In a child:

    Head (front and back) is 18%
    Back is 18%
    Chest is 18%
    Right arm is 9%

Left arm is 9%
Perineum is 1%
Right leg is 13.5%
Left leg is 13.5%

- It is important to identify the depth of a burn, as this will determine anesthetic and surgical management.
  - First degree burns have characteristics of erythema, pain, and absence of blisters. Examples: sunburn.
  - Second degree burns are also known as partial thickness burns, and features include red or mottled appearance. Examples: flash burns, burns from contact with hot liquids.
  - Third degree burns are also called full thickness burns, and characteristics include dark and leathery or dry appearance. Examples: fire, electricity or lightning, prolonged exposure to hot liquids or objects.
- Indications for hospitalization of a burn patient include:
  - Greater than 10% TBSA in a child.
  - Very young patient.
  - Any full thickness burn.
  - Burns of the face, hands, feet, and perineum.
  - Circumferential burns.
  - Inhalation injury.
  - Associated trauma or pre-burn co-morbidities.

What type of care will a patient receive in the burn intensive care unit (BICU)? [1–3]

- Wound debridement:
  - Initially, burns are sterile.
  - The focus is on fast healing and infection prevention.
  - BICU staff will perform the following:

    Debride all bullae.
    Excise adherent necrotic tissue.
    Gentle scrubbing to remove loose necrotic tissue.
    Apply a thin layer of antibiotic cream:

    - Silver sulfadiazine.
    - Bacitracin.

    Dress the burn with petroleum gauze and dry gauze.
- Escharotomies and fasciotomies:
  - Circumferential burns to chest and abdomen can create a restrictive ventilatory defect.

  - Circumferential burns to the limb can result in compartment syndrome. There can be increased pressure due to edema under rigid, burned skin. This impedes circulation and results in tissue death.
  - These are typically done on initial admission to the BICU while under sedation.

- Resuscitation:
  - Ensure adequate oxygenation and ventilation.
  - Recognize that the patient is in a hypermetabolic state.
  - Suspect carbon monoxide and treat with 100% FiO_2.

    Be wary of falsely elevated, unfractionated pulse oximetry readings.
    To distinguish, it will be necessary to use co-oximetry to differentiate oxy-hemoglobin from carboxy-hemoglobin.

  - Fluid resuscitation:

    Start with the Parkland formula of 4 cc/kg fluid bolus, with the first half to be given in the first 8 hours and the second half to be given in the next 16 hours.
    Run a maintenance rate of 4/2/1 cc/kg/hr., with 4 cc/kg/hr. for the first 10 kg total body weight, 2 cc/kg/hr. for the next 10 kg, and 1 cc/kg/hr. for every kg thereafter.
    Correlate the resuscitation with urine output.

    - Goal urine output is >0.5–1 cc/kg/hr. in adults and > 1–1.5 cc/kg/hr. in children.

    Correlate the resuscitation with hemodynamics.

  - Be mindful of the development of coagulopathies due to anemia, thrombocytopenia, and dilution of coagulation factors, due to excessive crystalloid and colloid administration.
  - Crossmatch blood products and be prepared to transfuse packed red blood cells, fresh frozen plasma, and platelets.

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Chapter 10
Button Battery Foreign Body (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss intraoperative management of suspected airway vs. esophageal foreign body.
2. Identify causes of respiratory distress post-extubation.
3. Discuss management of post-extubation stridor.

Simulator Environment

1. Location: operating room of a children's hospital
2. Manikin setup:
   (a) Age: infant
   (b) Lines: 1 x 22 Gauge (G) peripheral intravenous (PIV) catheter in foot – which the learner will find is infiltrated.
   (c) Monitors: none on patient at start of case

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3. Medications available: normal saline, propofol, dexmedetomidine, ketamine, midazolam, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, dexamethasone.
4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 3-lead electrocardiogram (EKG).
   (c) Lines: 24 G and 22 G PIV catheters, intraosseous kit, tourniquet, IV pigtail and flush.
   (d) Additional equipment: vein finder, ultrasound.
   (e) Crash cart with defibrillator
   (f) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy assisting the surgeon and setting up equipment. They are hesitant to get involved when the patient is agitated and the learner needs help restraining the child for an awake PIV.
2. Circulator nurse
   (a) The nurse is helpful and attentive. When the patient appears to be struggling to breathe after extubation, the nurse points out all signs that the patient is having respiratory distress and asks the anesthesiologist if they planx to reintubate and go to the pediatric intensive care unit (PICU).
3. Surgeon
   (a) The surgeon is efficient and able to remove the foreign body quickly.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist starting a case of a 13-month-old, 11 kilogram (kg) boy who is having a button battery removed from the esophagus. It is 10 pm. Around 6:30 pm, the dad saw his son climb up to the dinner table and

picked up a button battery and put it in his mouth. Since then, he noticed that his son has been breathing fine but drooling a lot. He took him straight to the emergency department (ED). A PIV was placed and a chest radiograph (CXR) anterior-posterior (AP) and lateral was done that is strongly supportive of a single button battery being present in the esophagus.

(b) Preoperative history: ex-full term; healthy; no recent upper respiratory infection (URI) symptoms; eating and growing well, meeting all developmental milestones; ate dinner about 3 hours prior to surgery.
(c) Preoperative physical: well-nourished infant resting comfortably in mom's arms, breathing comfortably on room air.
(d) Preoperative vital signs: within normal limits (WNL).
(e) Preoperative labs: none.

2. Scenario development

(a) Phase 1: awake PIV placement in agitated child

(i) The learner may start to place monitors on the patient first. The patient is initially tearful and starting to cry, but overall cooperative, remaining on the operating room (OR) table.
(ii) When the learner eventually tries to administer medications through the PIV, the child will scream and pull away and the skin will turn red and appear raised, indicating that the PIV has infiltrated and no longer functional.
(iii) The nurse will ask the learner if they can just mask the patient and place the PIV asleep. The learner should recognize that this patient is a full stomach with a possible airway foreign body, so the patient requires an awake PIV.
(iv) The child will begin to struggle more and try to get off of the OR table and run away. The learner should ask the nurse / scrub tech / surgeon / assistants to help restrain the child so they can place a new PIV. For this scenario, the patient will not be a difficult PIV. The learner will be able to place the PIV successfully on the first attempt.

(b) Phase 2: mild laryngospasm during laryngoscopy.

(i) The surgeon wants the anesthesiologist to keep the patient spontaneously ventilating so they can do a suspension laryngoscopy, survey the tracheobronchial tree quickly, and make sure there is no foreign body in the airway. After that, the surgeon plans to intubate the patient and proceed with upper endoscopy and removal of the esophageal foreign body.
(ii) The learner may do a combination of inhaled and IV anesthetic to induce the patient. The learner must be careful to watch the child and

make sure they are spontaneously ventilating, since the table will be turned 90 degrees and the chest / abdomen will be covered with a blue towel and a suspension laryngoscope.

(iii) The learner should provide supplemental oxygen. Options include nasal cannula, oxygen attached to side port of laryngoscope, or deep oxygen insufflation using an ETT placed in the oropharynx/proximal larynx.

(iv) During suspension laryngoscopy, the surgeon will report that the child seems a bit light and has coughed and laryngospasmed. The learner will need to decide whether and how to intervene. Options include deepening the anesthetic with propofol infusion / bolus, dexmedetomidine infusion / bolus, or ketamine bolus. The child will not desaturate. The laryngospasm will resolve before the learner tries to give succinylcholine.

(c) Phase 3: post-extubation stridor

(i) The surgeon will report that the survey of the tracheo-bronchial tree shows no foreign body, so they are confident that the foreign body is in the esophagus. The surgeon will go ahead and intubate the child since they are already at the head of the bed with a good view of the vocal cords. *The surgeon will not ask what size ETT to use. They will go ahead and insert whatever ETT is handed to them by the scrub tech. The tube happens to be 4.5 cuffed ETT, which is too large for the child. The surgeon will state that it's a bit snug and there's some resistance, but they were able to pass it and will proceed.*

(ii) *The learner may choose to check for a cuff leak or recommend downsizing the ETT to a more appropriate size. This is acceptable and smaller cuffed ETTs will be available.*

(iii) The surgeon will quickly remove the button battery from the esophagus, the table will be turned with the head back to the anesthesiologist. The learner will proceed to extubate the patient.

(iv) After extubation, the patient will display stridor and respiratory distress – tracheal tugging, sternal retractions, audible stridor heard outside the door, only mildly alleviated by repositioning the patient by turning them onto their side, oxygen saturation (SpO_2) 96% on 4 liters (L)/minute (min) simple face mask.

(v) The learner must decide how to proceed – whether to reintubate and go to PICU, to wait and watch in the OR, to take to post-anesthesia care unit (PACU) and try administering racemic epinephrine.

(vi) The scenario will end here.

Scoring Rubric

Table 10.1 Scoring rubric for case scenario on Button Battery Foreign Body Ingestion

Topic: Button Battery Foreign Body		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Vascular access		
Identifies infiltrated in situ peripheral intravenous (PIV) line		
Removes infiltrated PIV		
Identifies need for awake PIV		
Places awake PIV in a timely fashion		
Laryngospasm		
Maintains spontaneous ventilation under general anesthesia		
Maintains anesthetic with IV and/or inhaled agents		
Provides supplemental oxygen (options: Nasal cannula, side port of laryngoscope, endotracheal tube (ETT))		
Identifies laryngospasm		
Treats laryngospasm (deepens anesthetic with propofol, precede, ketamine)		
Recognizes that patient is stable and does not require administration of muscle relaxant to break the laryngospasm		
Post-extubation stridor		
Gives appropriate-sized ETT to surgeon for intubation at end of surgery		
Administers high dose dexamethasone 0.5 milligrams (mg)/kilogram (kg) (max 12 mg)		
Identifies signs of respiratory distress after extubation: Tracheal tugging, sternal retractions, audible stridor		
Attempts to treat respiratory distress: 1. Repositions patient (lateral decubitus)		
2. Provides continuous positive airway pressure (CPAP) via circuit face mask		
3. Inserts nasal trumpet or oral airway		
4. Provides chin lift or jaw thrust manually		
5. Provides 100% fraction of inspired oxygen (FiO_2)		
Communicates to surgeon that patient is in respiratory distress		
Identifies post-extubation stridor as cause of respiratory distress		
Assesses severity of respiratory distress based on vital signs and appearance of patient's breathing		
Makes disposition plan based on clinical severity: (a) may decide to reintubate and go to the pediatric intensive care unit (PICU), or (b) may decide to remain extubated and go to the post-anesthesia care unit (PACU) and administer racemic epinephrine		

Summary of Clinical Teaching Points

Do you need an awake peripheral intravenous (PIV) line in a child with an ingested or aspirated foreign body? [1–4].

Table 10.2 Considerations for placing an awake peripheral intravenous line in a pediatric patient

Considerations	Strategies
What are the indications for an awake peripheral IV?	Known or anticipated difficult airway – Difficult intubation and/or difficult mask ventilation Anticipated difficult airway due to airway foreign body Full stomach – Recent per oral intake, trauma, full stomach, delayed digestion
How do you manage an agitated child?	Multiple providers to help restrain the child Optimize first attempt at peripheral IV placement with an experienced provider Weigh the pros/cons of having a parent in the operating room
How do you handle a difficult peripheral IV?	Ultrasound guidance Vein finder Central line – Femoral vein may be easiest in awake child who is unable to remain still Intraosseous line – Tibial placement often most accessible

What is the anesthetic management of an aspirated or ingested foreign body? [1–4]

- General anesthetic – no response to surgical stimulus (bronchoscopy, esophagoscopy)
- Goal is to maintain spontaneous ventilation until it is safe to intubate the patient and establish a secure airway
  - Highly stimulating but not painful procedure, hopefully of short duration
  - Deep enough anesthetic that you avoid patient coughing/bucking, laryngospasm, bronchospasm, or dislodgement of the foreign body
  - No accurate end-tidal carbon dioxide ($ETCO_2$) available
  - Rely on visualization of chest rising and falling to confirm spontaneous ventilation intact
  - Supplemental oxygen sources: nasal cannula, ventilator circuit to side port of bronchoscope, endotracheal tube (ETT) in the oropharynx

- Drugs of choice
  - Avoid volatile anesthetic – open field, caution against polluting operating room environment and exposing staff to volatile anesthetic
  - Propofol infusion (good starting point 200–250 micrograms (mcg)/kilogram (kg)/minute (min)) + boluses in line
  - Dexmedetomidine boluses
  - Ketamine boluses
  - Spray the vocal cords with lidocaine

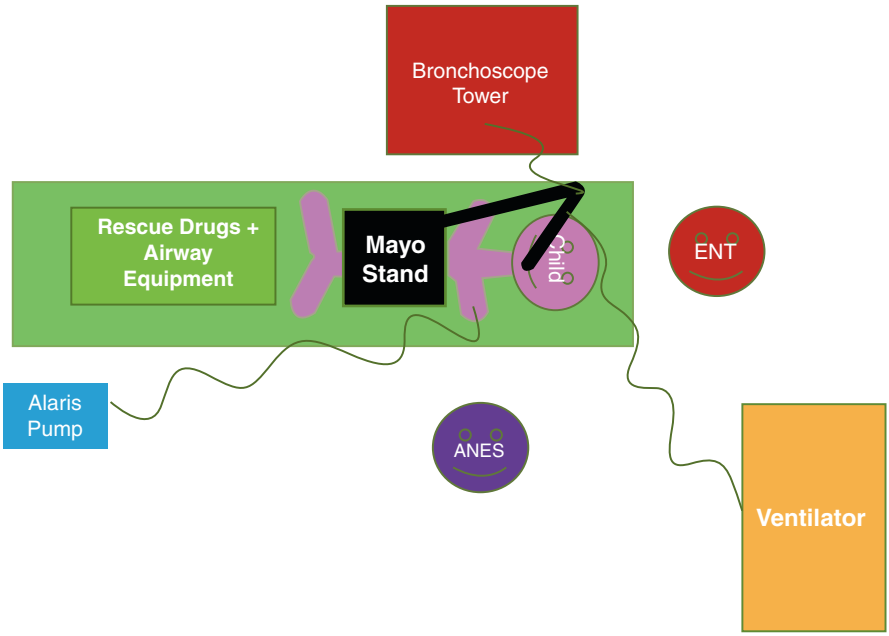

Fig. 10.1 Diagram of layout of equipment for shared airway procedures

What could possibly go wrong?

Table 10.3 Common complications and management strategies for removal of ingested and aspirated foreign bodies

Problem	Solution
Light anesthetic → coughing/bucking → laryngospasm, bronchospasm → oxygen desaturation	Albuterol – Limited route of administration when no secured airway Epinephrine – How much do you give? Good starting dose is 0.1 micrograms (mcg)/kilogram (kg). If in cardiac arrest, code dose is 10 mcg/kg Succinylcholine – Consider how much is a "small dose" for your patient (e.g. standard intubating dose is 1–2 milligrams (mg)/kilogram (kg)). Consider how you will re-establish ventilation after administering succinylcholine – May need to temporarily place an endotracheal tube, wait for paralysis to resolve and oxygen levels to rise, and then extubate and resume surgery Supplemental oxygen – Consider multiple routes of administration, such as nasal cannula, side port of bronchoscope, endotracheal tube, face mask
Apnea	Intubate – Consider potential for dislodging the foreign body in an even less accessible location Mask ventilate – Consider potential for full stomach, foreign body in trachea that may become dislodged in difficult-to-reach location, and challenges of mask ventilating with table turned 90 degrees Jet ventilate – Consider potential for dislodging an airway foreign body, caution with using appropriate pressures in a pediatric patient, may not be readily available
Foreign body or multiple foreign bodies that are difficult to remove	Continue to optimize anesthetic and provide a motionless surgical field for the surgeon Be prepared for the foreign body to become dislodged and impede ability to maintain two-lung ventilation
Foreign body becomes dislodged and completely occludes trachea, resulting in absent ventilation and absent oxygenation	Give the ear/nose/throat (ENT) surgeon an endotracheal tube and tell them to intubate the patient and purposefully right mainstem the foreign body. Begin one-lung ventilation. Not ideal but at least you'll restore some degree of ventilation and oxygenation
Failure to ventilate, failure to oxygenate, resulting in cardiac arrest	Initiate Pediatric advanced life support (PALS), including chest compressions, intubation, and administration of epinephrine 10 micrograms (mcg)/kilogram (kg) intravenously (IV)

What are common causes of post-extubation respiratory distress?

Remember to maintain constant vigilance, especially during emergence and extubation. There are many stressors in the operating room that may lead us to cut corners or rush through emergence and extubation and transport from the OR to the PACU. In the grand scheme of things, no one will remember if you stayed in the OR 5 minutes longer to safely extubate your patient. But if you bring a blue (cyanotic) and apneic patient to PACU and have to emergently reintubate, people will definitely remember you.

We often look to common physical signs as evidence of breathing and successful extubation. However, in the busy operating room with a small pediatric patient, it can be easy to misinterpret these as successful indicators of a well-ventilating patient. The following table describes how these signs can be misinterpreted and result in failure to recognize apnea.

Table 10.4 Common physical signs of ventilation that are misinterpreted post-extubation

Signs of Breathing	Source of Confusion	Possible Remedies
Fogging of face mask	Small child – May be hard to see fogging of small face mask on a small child Glare – Fluorescent light reflecting on plastic may be misconstrued as fogging	Pinch the face mask gently around the nose to observe fogging in concentrated area
Rise and fall of chest	Small child – Hard to see the chest rise and fall Blankets/gown – Cover up provider's view of chest wall movement Heart beating – In small child, chest wall movement from heart beating can be misinterpreted as chest rise/fall from lungs expanding	Remove gowns and blankets to expose chest and abdomen. Enables provider to observe chest and abdomen rise/fall, as well as pattern of breathing and coordination of chest and abdominal wall movements. Put your hand on the chest gently to feel it rise and fall.
Green bag on ventilator or Mapleson inflating and deflating	If you have a poor seal of your face mask, you will have a leak and will not be able to see the green bag inflating (exhalation) and deflating (inhalation)	After extubation, immediately place face mask on the patient to obtain good seal. Provide chin lift and neck flexion/head extension to optimize positioning. Check for green bag inflating and deflating and for positive end-tidal carbon dioxide ($ETCO_2$) on capnogram.
Audible breathing peripherally	In a small child/infant in a noisy environment, you may not hear audible breathing peripherally.	Listen with your stethoscope. Ask for quiet and attention in the room at the time of emergence/extubation.
Pink versus cyanotic appearance	An inexperienced provider may erroneously dismiss cyanosis as the patient's natural skin tone or poor lighting.	Always take discoloration seriously and assume it is cyanosis until proven otherwise. Check the pulse oximeter readings. Re-check other confirmatory signs of adequate ventilation.
Breath sounds on auscultation	It is very difficult to fake spontaneous breath sounds on auscultation. This is a reliable indicator of appropriate ventilation.	Use your stethoscope frequently: Immediately after extubation, after repositioning patient from the OR table to the transport gurney/bed, and upon arrival in the PACU. Ask for quiet and attention in the OR at the time of emergence/extubation. Turn off the Bair hugger. Minimize other noise distractions.

What are possible post-extubation complications in pediatric patients?

Table 10.5 Common causes of pediatric post-extubation complications

Event	Cause	Prevention and Treatment
Upper airway obstruction	Excessive narcotics Obstructive sleep apnea	Larger adolescent: Reposition to head of bed elevated Smaller: Reposition to lateral decubitus position with head extension
Laryngospasm	Deep extubation / laryngeal mask airway (LMA) removal Secretions Stage 2 emergence/extubation	Ensure adequate ventilation prior to leaving the operating room Minimize secretions by thoroughly suctioning Minimize head/neck manipulation post-extubation
Stridor	Airway edema Traumatic intubation Nerve injury	Early recognition Intravenous dexamethasone Racemic epinephrine Head of bed elevation
Bronchospasm	Recent upper respiratory infection Known asthma	Albuterol nebulizer Intravenous epinephrine

What are strategies for early detection and intervention on post-extubation apnea?

It is important to establish a through systematic approach that you can do routinely with every extubation to ensure that you can identify and treat post-extubation apnea. The following is one such strategy.

1. Confirm that the current stage of anesthesia is the intended stage of anesthesia for extubation. You can extubate in stage 1 (awake) or stage 3 (deep), depending on the patient and surgery. You should never extubate in stage 2.
2. Suction the oropharynx well. Minimize secretions as much as possible.
3. Extubate.
4. Immediately after extubation, put the face mask on the patient, obtain a good seal, provide chin lift and/or jaw thrust, neck flexion, and head extension, and close the airway pressure release valve to 5–10 centimeters of water (cmH_2O) to deliver continuous positive airway pressure (CPAP).
5. Identify signs of adequate ventilation:
   (a) Positive ETCO2 on capnogram.
   (b) Visualize/palpate the circuit green bag inflating and deflating.
   (c) Visualize chest rising and falling.
   (d) Auscultate breath sounds using stethoscope.
   (e) Auscultate breath sounds peripherally.
   (f) Visualize fogging of face mask.

6. If at any point, any one of the above signs in Step 5 is missing, assume apnea and intervene.
7. If all of the above criteria in Step 5 are met, then assume adequate ventilation and proceed next step.
8. Gradually release CPAP.
9. Ensure all signs of adequate ventilation from Step 5 are still met. If so proceed to next step.
10. Gradually release chin lift and/or jaw thrust.
11. Ensure all signs of adequate ventilation from Step 5 are still met. If so proceed to next step.
12. Transition from circuit face mask to simple face mask.
13. Move patient from OR table to transport gurney/bed.
14. Confirm adequate ventilation.
    (a) Visualize chest rising and falling.
    (b) Auscultate breath sounds using stethoscope.
    (c) Auscultate breath sounds peripherally.
    (d) Visualize fogging of face mask.
15. Transport to the PACU or other post-op destination (e.g. PICU).
16. Before completing handoff and leaving the patient's bedside, again confirm adequate ventilation.
    (a) Visualize chest rising and falling.
    (b) Auscultate breath sounds using stethoscope.
    (c) Auscultate breath sounds peripherally.
    (d) Visualize fogging of face mask.

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Chapter 11
Code Sepsis (Adult)

Suraj Trivedi

Case Outline

Learning Objectives

1. Identify symptoms of sepsis.
2. Understand the hemodynamic markers and labs that indicate a septic state.
3. Correctly initiate treatment according to the Surviving Sepsis guidelines.
4. Effectively communicate with surgeons regarding intraoperative complications.

Simulator Environment

1. Location: operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 2 x large bore peripheral intravenous (PIV) catheters
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, dopamine, phenylephrine, ephedrine, albumin, lactated ringers, vasopressin, epinephrine, nitroglycerin, norepinephrine.

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4. Equipment available:
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), and suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 3-lead EKG.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator

Actors

1. Surgeon
2. Circulator nurse

Case Narrative

1. Scenario background given to participants:
   (a) The patient is a 55-year-old female status post combined kidney and liver transplant from deceased donors. She is postoperative day #1 and remains intubated in the intensive care unit (ICU). She is scheduled for urgent take-back to the operating room for continued bleeding.
   (b) Currently she is hemodynamically stable on propofol and fentanyl infusions.
   (c) Past medical history is notable for type 2 diabetes mellitus, non-alcoholic steatohepatitis, hepatorenal syndrome, and congestive heart failure.
   (d) Current access: 2 x large bore PIVs, arterial line, and central line
   (e) Labs from 2 hours ago show:
      (i) Arterial blood gas: pH 7.32, $PaCO_2$ 40, PaO_2 100, HCO_3 23.
      (ii) Complete blood count (CBC): white blood count (WBC) 14, hemoglobin (Hb) 8.2, hematocrit (Hct) 29, Platelet 80.
      (iii) Basic metabolic panel (BMP): sodium (Na) 133, potassium (K) 3.3, Glucose 80.
   (f) Chest radiograph (CXR) the morning of surgery demonstrated cardiomegaly with bilateral patchy infiltrates.
2. Scenario development
   (a) Phase 1: septic state
      1. The surgeons have started closing the abdomen and now the patient is becoming increasingly hypotensive, tachycardiac, and hypothermic.

(i) The student learner should communicate closely with the surgeons about the hemodynamic changes and vital signs.
(ii) The learner should inquire about any intraoperative surgical complications.
(iii) The surgeons will communicate that they had found a bowel leak which was not previously reported to the anesthesiologist. The surgeons report that the bowel has since been repaired and the abdominal cavity has been irrigated well.
(iv) The learner should express concern that that patient may be becoming septic due to leakage of the bowel contents.
(v) The learner should stabilize the patient's hemodynamics:

2. Fluid bolus: crystalloids 20–40 milliliters (mL)/kilogram (kg), albumin 10 milliliters (mL)/kilogram (kg).
3. Inotropes
4. Pressors

(vi) The learner should send repeat labs and cultures:

5. Blood culture
6. Urine culture
7. Serum lactate
8. Arterial blood gas (ABG)
9. Complete blood count (CBC)
10. Basic metabolic panel (BMP)

(vii) The learner should discuss with the surgeon starting broad spectrum antibiotics.

(b) Phase 2: abdominal compartment syndrome

(i) As the surgeons close the fascia, the patient will develop elevated peak pressures and worsening hypotension.
(ii) The learner should suspect abdominal compartment syndrome and notify the surgeons.
(iii) The surgeons will report that the bowel is quite edematous.
(iv) The learner should discuss with the surgeons the possibility of leaving the abdomen open and doing a staged closure later, especially if further washouts are required.
(v) The learner should rule out other causes of hypotension.
(vi) The learner should consider a trans-thoracic echocardiogram (TTE) or trans-esophageal echocardiogram (TEE) to evaluate for septic cardiomyopathy.
(vii) Echocardiogram will be notable for slightly underfilled heart that is hyperdynamic, including septic cardiomyopathy and inadequate volume resuscitation.

Scoring Rubric

Table 11.1 Scoring rubric for case scenario on Sepsis

Topic: Sepsis			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Sepsis			
Evaluation	Communicates with surgeons about hemodynamic changes		
	Identifies sepsis as differential diagnosis.		
Management	Administers fluid bolus: Crystalloids 20–40 milliliters (mL)/kilogram (kg), albumin 10 mL/kg		
	Administers inotropes/pressors: Epinephrine, vasopressin, norepinephrine, dopamine, etc.		
	Sends pan-cultures: Blood culture, urine culture		
	Checks labs: Serum lactate, arterial blood gas (ABG), complete blood count (CBC), basic metabolic panel (BMP)		
	Initiates broad spectrum antibiotics		
Abdominal compartment syndrome			
Evaluation	Identifies abdominal compartment syndrome as differential diagnosis		
	Checks ventilator circuit, endotracheal tube (ETT), ventilator settings, capnogram, and manually bags patient when peak pressure alarm occurs		
	Communicates with surgeons about elevated peak pressure and difficulty ventilating patient		
	May switch to pressure control mode of ventilation		
	Considers other etiologies of hypotension: Preload, afterload, contractility, rate, and rhythm		
	Performs trans-thoracic echocardiogram (TTE) or trans-esophageal echocardiogram (TEE) to evaluate for cardiac function		
	Identifies echocardiogram abnormalities: Hyperdynamic heart, underfilled ventricles		
	Identifies septic cardiomyopathy based on echocardiogram findings		
Management	Continues to volume resuscitate patient based on echocardiogram findings		

Summary of Clinical Teaching Points

What is sepsis?

- Generally speaking, sepsis is life-threatening organ dysfunction caused by dysregulated host response to infection [1].
- Definitions of sepsis have changed over time.
- SEPSIS 1 clinical trial (1991):
  - "Systemic inflammatory response syndrome," also known as SIRS, and was defined as including hypothermia or hyperthermia, tachycardia, tachypnea, and leukocytosis.
  - "Sepsis" meant that 2 or more SIRS criteria were met.
  - "Severe sepsis" meant sepsis plus organ dysfunction.
  - "Septic shock" meant sepsis-induced hypotension despite adequate fluid resuscitation [2].
- SEPSIS 2 clinical trial (2003):
  - "Sepsis" was defined as SIRS criteria plus a known infection [2].
- SEPSIS 3 clinical trial (2016):
  - "Sepsis" criteria meant 2 out of 3 points on Quick Sequential Organ Failure Assessment (qSOFA) scoring
  - "Sepsis" was defined as suspected or documented infection plus an acute increase greater than 2 in the Sequential Organ Failure Assessment (SOFA) score
  - "Septic shock" meant sepsis plus the requirements of vasopressors to keep the mean arterial pressure (MAP) greater than 65
  - The terms "SIRS" and "severe sepsis" are no longer used because they are non-specific [2].

What are the criteria for the Sequential Organ Failure Assessment (SOfA) score?

Table 11.2 Criteria for calculating the Sequential Organ Failure Assessment (SOFA) score [3]

SOFA Score	0	1	2	3	4
Respiration PaO_2/FiO_2 (mmHg)	>400	301–400	201–300	101–200	≤100
Coagulation Platelets ($x10^3/mm^3$)	>150	101–150	51–100	21–50	≤20
Liver Bilirubin (mg/dL)	<1.2	1.2–1.9	2.0–5.9	6.0–11.9	≥12.0
Cardiovascular Hypertension	No hypotension	MAP <70 mmHg	Dopamine ≤5 mcg/kg/min or dobutamine (any dose)	Dopamine >5 mcg/kg/min	Dopamine >15 mcg/kg/min
Central nervous system Hypotension	15	13–14	10–12	6–9	<6
Renal Creatinine (mg/dL) or urine output	<1.2	1.2–1.9	2.0–3.4	3.5–4.9 <500 ml/day	>5.0 <200 ml/day

What is the Quick SOFA score?

- The full SOFA score requires laboratory values and may be less predictive for a patient outside of the intensive care unit (ICU).
- The Quick SOFA score was developed for use outside the ICU.
- qSOFA scoring components:
  - Glasgow Coma Scale (GCS) score <15
  - Systolic blood pressure <100 mmHg
  - Respiratory rate >22 breaths/minute
- If the patient meets 2 out of 3 points, then this is considered a positive qSOFA score [2].

What is shock?

- Shock is defined as circulatory failure that results in inadequate cellular oxygenation and oxygen utilization.
- What are the different types of shock?
  - Cardiogenic
  - Hypovolemic
  - Anaphylactic
  - Septic
  - Neurogenic
- What are the signs of shock by organ system?
  - Neurologic: altered mental status, confusion, disorientation

  - Cardiovascular: hypotension, arrhythmias, cyanosis, rising lactate, peripheral pulses often weak and rapid, chest pain
  - Pulmonary: dyspnea, tachypnea, hyperventilation
  - Gastrointestinal: nausea, vomiting, diarrhea, abdominal pain
  - Renal: decreased urine output [4]

How is sepsis treated?

- In 2001, there was the philosophy of early goal-directed therapy, but this was very resource-intensive and required central venous pressure (CVP) and central venous oxygen saturation ($S_{cv}O_2$) measurements.
- In 2015 came the PROCESS, ARISE, and PROMISE trials, which demonstrated that early goal-directed therapy was not superior to usual critical care practices, but that early fluids and antibiotics were essential [5, 6].
- Early antibiotics are important, and were shown to decrease mortality by 7%.
- Volume resuscitation is defined as crystalloid bolus of 30 mL/kg.
- Blood transfusion should be done for hemoglobin (Hb) < 7 g/dL.
- Vasopressors should be used to keep the mean arterial pressure (MAP) > 65 in patients who do not respond to fluids.
- Source control of infection is important.

What is abdominal compartment syndrome?

- Intra-abdominal hypertension is defined as intra-abdominal pressure ≥ 12 mmHg.
- Abdominal compartment syndrome is defined as an intra-abdominal pressure ≥ 20 mmHg with evidence of organ dysfunction or failure.
  - Primary abdominal compartment syndrome is due to injury or disease within the abdominal-pelvic region, such as trauma, intra-abdominal hemorrhage, laparoscopy, peritonitis, and massive fluid resuscitation.
  - Secondary abdominal compartment syndrome is due to conditions outside of the abdomen, such as sepsis, capillary leakage, and major burns.

What are the systemic consequences and anesthetic challenges due to sepsis?

Table 11.3 Anesthetic challenges of sepsis by organ system [1]

System	Challenge
Neurologic	Increased intracranial pressure
Cardiovascular	Decreased preload Decreased venous return Decreased cardiac output Increased pulmonary pressure
Pulmonary	Increased peak pressure Decreased compliance (lower tidal volume for given pressure)
Renal	Decreased renal perfusion
Gastrointestinal	Decreased bowel perfusion

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Chapter 12
Craniosynostosis (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Review the anesthetic management of craniosynostosis repair.
2. Discuss management of hyperkalemia.
3. Discuss indications and guidelines for transfusion.

Simulator Environment

1. Location: operating room in a children's hospital
2. Manikin setup: (learner will be taking over after incision was made about 30 minutes prior)
   (a) Age: infant
   (b) LDAs: 22 gauge (G) peripheral intravenous (PIV) catheter saphenous, 24 G PIV hand, 24 G radial arterial line, femoral central line double lumen 5 French, foley catheter w/ temperature probe
   (c) Monitors: pulse oximeter, blood pressure cuff, 3-lead electrocardiogram (EKG), arterial line, temperature, capnogram

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3. Medications available: normal saline, albumin, propofol, succinylcholine, rocuronium, epinephrine, phenylephrine, albuterol, fentanyl, ketamine, dopamine, tranexaminic acid, calcium chloride, cefazolin, dexamethasone, sodium bicarbonate, insulin, dextrose 50% (D50), furosemide.
4. Additional equipment available
   (a) Crash cart with defibrillator
   (b) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy assisting the neurosurgeons. The bleeding is more than expected.
2. Circulator nurse
   (a) The circulator nurse is helpful. If the learner doesn't walk around the table to survey the surgical field / suction canister / wet laps on the hanger, the circulator nurse will eventually come over to the learner and whisper that the bleeding seems more than usual.
3. Surgeon
   (a) The surgeon is focused on controlling the bleeding, which is more than usual. If the learner has not given any blood yet, the surgeon will ask the learner how much blood they have transfused so far.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist taking over for another anesthesiologist who is in a rush to sign out and leave. The signout is that the patient is a 9-month-old, 10 kilogram (kg) baby boy with no cardiac or pulmonary problems, whose only medical history is the craniosynostosis associated with seizures, for which he is maintained on Keppra and has been seizure free for 3 months. He is mildly delayed with motor and speech milestones, but is overall eating and growing well.

(b) Preoperative vital signs: none
(c) Preoperative labs: none.

2. Scenario development

(a) Phase 1: recognition of significant hemorrhage requiring transfusion.

(i) Starting vital signs when the learner takes over the case are heart rate (HR) 110 sinus tachycardia, blood pressure (BP) 80/50, pulse pressure variation (PPV) of 13, oxygen saturation (SpO_2) 99%, T 36.5. First arterial blood gas (ABG) drawn at initial arterial line insertion showed potassium (K) 4.0, hemoglobin (Hb) 11.8, bicarbonate (HCO_3) 25. The previous anesthesiologist had not started transfusing yet, and no blood is in the room. The blood is all in an operating room (OR) fridge nearby.
(ii) There should be significant movement in the OR indicating that the surgeons, scrub tech, and circulator nurse are working hard. The surgeons will repeatedly request additional laps, suction, and equipment, and may comment that there is more bleeding than expected and they have struggling to control it.
(iii) The vital signs will gradually worsen: worsening tachycardia HR 130 s, hypotension BP 65/40, increased PPV 18, desaturation SpO_2 96%.
(iv) If the learner walks around to survey the room, they will notice that the surgical field is quite bloody, the drapes are soaked, there is a puddle of blood on the floor, the suction canister is full, and there are many wet laps.
(v) If the learner asks how things are looking in the surgical field, the surgeon will comment that it is slow oozing, with a few small bleeders, but still more than they expected. The surgeon will ask how much blood the patient has been given so far.

(b) Phase 2: transfusion of blood products.

(i) The learner should at this point recognize hemorrhage and initiate transfusion of blood products. Available products are packed red blood cells (PRBCs), fresh frozen plasma (FFP), and platelets. A runner will quickly bring the transport box of blood products into the room.
(ii) If the learner is slow to recognize the hemorrhage and does not transfuse soon, the patient will further decompensate: now becoming bradycardic HR 60s, BP 45/25, desaturation SpO2 80s%.
(iii) If the learner checks another ABG, it will show K 5.0, Hb 7.1, HCO_3 20.
(iv) The learner must decide whether to transfuse the blood through the PIV or through a central line, and decide how quickly to transfuse the blood.

(v) The learner may administer a bolus of crystalloid or colloid fluids while waiting for blood to be brought to the OR.
(vi) The learner may administer inotropic agents such as epinephrine bolus/infusion or dopamine infusion.

(c) Phase 3: development of cardiac arrest due to hyperkalemia.

(i) Regardless of the speed or route in which the learner transfused blood, the patient will develop cardiac arrest due to hyperkalemia.
(ii) Vital sign changes: tachycardia 120 s with peaked T waves ➔ ventricular tachycardia 140 s with a pulse, BP 50s/30s.
(iii) The learner should call for the crash cart and placement of defibrillator pads, and should cardiovert the patient at 0.5–2 Joules (J)/kilogram (kg).

(d) Phase 4: treatment of hyperkalemia.

(i) The learner should sent a repeat ABG, which will show K 7.5.
(ii) The learner should medically treat the hyperkalemia: hyperventilate, insulin 0.1 units/kg, D50 1 cc/kg, calcium chloride 10 mg/kg, sodium bicarbonate 1 mEq/kg, furosemide 0.5 mg/kg.
(iii) Repeat ABG will show improvement of K to 4.5. Vital signs will normalize.
(iv) This will mark the end of the scenario.

Scoring Rubric

Table 12.1 Scoring rubric for case scenario on Craniosynostosis

Topic: Craniosynostosis			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Hemorrhage			
Evaluation and communication	Walks around the operating room (OR) table to survey the surgical field, drapes, wet laps, suction canister, and irrigation volume		
	Asks surgeon about estimated blood loss (EBL) so far		
	Asks nurse about location and availability of blood products		
	Checks recent labs		

Table 12.1 (continued)

Management	Transfuses packed red blood cells (PRBCs), fresh frozen plasma (FFP), and/or platelets in balanced ratio		
	Transfuses appropriate volumes: PRBCs 10–15 cc/kg, FFP 10–15 cc/kg, platelets 5–10 cc/kg		
	Transfuses blood products cautiously/slowly		
	Transfuses blood products through peripheral intravenous (PIV) line rather than central line		
	Boluses with crystalloid 20 cc/kg and/or albumin 10 cc/kg until blood products arrive		
	Administers inotropes and/or pressors to support hemodynamics		
	Administers appropriate doses of inotropes and/or pressors: Ephedrine 0.1 mg/kg, phenylephrine 1 mcg/kg		
Hyperkalemia			
Evaluation	Checks repeat arterial blood gas s(ABG).		
	Identifies severe hyperkalemia		
Management	Hyperventilates with 100% fraction of inspired oxygen (FiO_2)		
	Administers calcium chloride 10 mg/kg intravenously (IV)		
	Administers albuterol puffs via the endotracheal tube (ETT)		
	Administers sodium bicarbonate 1 mEq/kg IV		
	Administers insulin 0.1 units/kg IV		
	Administers dextrose 50% 1 cc/kg IV		
	Administers furosemide 0.5 mg/kg I		
Arrhythmia			
Evaluation	Identifies electrocardiogram (EKG) changes indicative of hyperkalemia: Peaked T waves, ventricular tachycardia		
Management	Calls for crash cart		
	Checks for pulse		
	Initiates chest compressions		
	Places defibrillator pads		
	Appropriately cardioverts patient: If synchronized cardioversion 0.5–2 J/kg, if unsynchronized cardioversion 2–4 J/kg		

Summary of Clinical Teaching Points

What is craniosynostosis? [1–4]

- Craniosynostosis is a condition in which the bones of an infant's skull fuse together too early, instead of by age 2–3 years old.
- Complications that result from this premature fusion:
  - Head and facial deformities, possibly severe and permanent
  - Increased intracranial pressure
  - Seizures
  - Developmental delay
  - Poor feeding or projectile vomiting
  - Bulging eyes

What are the surgical steps involved in a craniosynotosis repair? What are the anesthetic considerations during these parts of the surgery? [1–4]

1. *Scalp dissection*: epinephrine solution is injected at the incision site for vasoconstriction. There can be possible inadvertent dural venous sinus tear.
2. *Craniotomy and bone flap removal*: significant bleeding can occur from the cut edges of the skull before application of bone wax. There is a possible risk of venous air embolism and massive bleeding from a dural venous sinus tear.
3. *Orbital osteotomies*: significant bleeding can occur; bradycardia can result from tension/pressure on the eyes.
4. *Contouring/plating*: slow bleeding can occur.
5. *Closure*: it is important to ensure adequacy of hemostasis.

What are risk factors for hemorrhage during craniosynostosis repair? [1–4]

- Hemorrhage and hypovolemia are the most common perioperative challenges.
- Risk factors for bleeding include:
  - Weight < 10 kg
  - Age < 18 months
  - Craniofacial syndromes
  - Pansynostosis
  - Operating time > 5 hours
  - Re-do operations
  - High intracranial pressure pre-operatively

How do you estimate blood loss during craniosynostosis repair? [1–4]

- In pediatric anesthesia, especially, it is helpful to calculate the patient's estimated blood volume at the start of the case, and then set goals for a maximum allowable blood loss at which point you would strongly consider transfusion.

- For long cases with constant, slow, progressive blood loss, it is important that the anesthesiologist remain vigilant and monitor blood loss carefully.
  - Check the suction canisters. Note the volume in the suction canister compared to the volume of irrigation used.
  - Check the size and degree of soaked lap sponges.
  - Check the drapes and the floor.
  - Inspect the surgical field for hemostasis.
  - Communicate with the surgeons regarding degree of hemostasis.
  - Check hemoglobin levels at regular intervals and with changes in hemostasis or hemodynamics.
  - Note hemodynamic changes that indicate anemia or ongoing blood loss – hypotension, tachycardia, increased pulse pressure variation.
- Estimating blood loss
  - 1 large wet lap sponge = 100 cc of blood
  - 1 small wet lap sponge/gauze = 10 cc of blood
  - Suction canister volume minus irrigant volume (can ask the scrub technician or the operating room nurse)
  - Back-calculate the estimated blood loss by the change in hemoglobin or hematocrit from the start of the case to the current lab value
  - Calculate the estimated blood volume (EBL)

    EBL = patient's weight (kg) x estimated blood volume (mL/kg)

  - Calculate the maximum allowable blood loss (MABL)

    MABL = [(starting Hct – lowest Hct) / starting Hct] x estimated blood volume

How do you estimate blood volume in a pediatric patient?

Table 12.2 Estimated blood volume by age

Age	Estimated Blood Volume (mL/kg)
Pre-term neonate	100
Full-term neonate	90
Infant	80
Child	75
Teenager	70
Adult	70

What are your options for blood transfusion and fluid resuscitation?

Table 12.3 Options for blood transfusion and fluid resuscitation, including indications for when to give, how to administer, and what laboratory changes to expect

Blood Product or Fluid	Special Preparation	When to Administer	How Much to Administer	Expected Change
Packed red blood cells (PRBCs)	Fresh PRBCs if patient is <7 days old Washed PRBCs if patient is <1 year old or weighs <10 kg	Hb < 8 Hct < 25 Clinically indicated based on ongoing blood loss and hemodynamics	10–15 cc/kg	Increases Hb 2–3 / Hct 6–9
Fresh frozen plasma (FFP)		Half the patient's blood volume has been replaced with PRBCs Excessive surgical oozing without a known cause	10–15 cc/kg	Increases factors by 15–20%
Platelets		Estimated blood loss is greater than 1–2 times the total blood volume Platelet count <100 K with further blood loss anticipated	5–10 cc/kg	Increases platelet count by 50–100 K
Cryoprecipitate		Extensive blood loss replaced with PRBCs and FFP Clinical or laboratory evidence of coagulopathy Hypofibrinogenemia	5–10 cc/kg	Increase fibrinogen by 60–100 mg/dL
Whole blood	< 7 days old		Replace blood loss on "cc per cc" basis	
Reconstituted blood	Mix donor-matched PRBCs and FFP Irradiated Washed if >7 days old		Replace blood loss on "cc per cc" basis	
Crystalloid	Normal saline Lactated ringers Plasmalyte		20 cc/kg bolus as a starting point	
Colloid	5% albumin		10 cc/kg bolus as a starting point	

What are the cardiac signs of hyperkalemia?

Table 12.4 Cardiac signs of hyperkalemia based on serum potassium level

Serum Potassium Level	Possible Cardiac Changes
Mild (5.5–6.5 mEq/L)	Peaked T waves Prolonged PR segment
Moderate (6.5–8.0 mEq/L)	Loss of P wave Prolonged QRS complex ST-segment elevation Ectpoic beats and escape rhythms
Severe (>8.0 mEq/L)	Progressive widening of QRS complex Sine wave Ventricular fibrillation Asystole Axis deviations Bundle branch blocks Fascicular blocks

What is the treatment of hyperkalemia in pediatric and adult patients?

Table 12.5 Pharmacologic management of hyperkalemia in adult versus pediatric patients

Adult Patient	Pediatric Patient (think Adult dose divided by 100 kg)
Hyperventilate	Hyperventilate
Insulin 10 units IV	Insulin 0.1 units/kg IV
D50% 1 ampule = 50 cc of dextrose 500 mg/mL = 25 grams of dextrose	D50% 0.5 mg/kg = 1 cc/kg D25% 0.5 mg/kg = 2 cc/kg
Calcium chloride 1 gram = 1000 mg	Calcium chloride 10 mg/kg ***administer slowly and cautiously, consider central venous access***
Sodium bicarbonate 1 ampule = 50 mEq / 50 mL	Sodium bicarbonate 1 mEq/kg = 1 cc/kg
Albuterol puffs	Albuterol puffs
Furosemide 20 mg	Furosemide 0.5 mg/kg (max 10 mg)

What is in a "shock"?

- "Shock" and "cardioversion" are frequently used terms that do not specify whether it is a synchronized or unsynchronized.
- "Defibrillation" specifically means "unsynchronized cardioversion."
- Unless you say "synchronized cardioversion," it is not clear that you want "synchronized" versus "unsynchronized."
- Cardioversions are often done in emergent settings where there can easily be miscommunication and medical errors. It is important to use clear, precise terminology and closed loop communication to avoid medical error.
- What are the "shockable rhythms" and what does "shockable" mean?
  - "Shockable rhythm" in this setting refers to arrhythmias that should be treated with an "unsynchronized cardioversion."
  - "Shockable rhythms" include (1) ventricular fibrillation and (2) ventricular tachycardia without a pulse.
- What is not a "shockable rhythm"?
  - Asystole
  - Pulseless electrical activity
- What arrhythmia may need to be treated with a "synchronized cardioversion," especially in the setting of hemodynamic instability?
  - Ventricular tachycardia with a pulse
  - Supraventricular tachycardia
  - Atrial fibrillation

How do you program the defibrillator for cardioversion?

Table 12.6 Dosing for synchronized versus unsynchronized cardioversions in adult versus pediatric patients

	Adult Dose	Pediatric Dose
Synchronized cardioversion	Biphasic: Use manufacturer recommendations. Typically start at 120 J and up-titrate to 200 J. second and subsequent doses should be equivalent, and higher doses may be considered. If you're not sure, it is ok to start at 200 J.	Biphasic: 0.5–2 J/kg, with a maximum dose of 200 J
Unsynchronized cardioversion	200 J	2–4 J/kg, up to 10 J/kg, with a maximum dose of 200 J

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Chapter 13
Delivery Room Resuscitation (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Review neonatal resuscitation protocol.
2. Review differential diagnoses for respiratory distress in a neonate.
3. Learn how to place an umbilical venous catheter in a neonate.

Simulator Environment

1. Location: operating room of labor and delivery floor in adult hospital
2. Manikin setup:
   (a) Age: neonate
   (b) Lines: none at presentation; umbilical cord stump is available
   (c) Monitors: none on patient at start of case
3. Medications available: normal saline, dextrose 5%- half normal saline, dextrose, propofol, succinylcholine, rocuronium, epinephrine, albuterol, atropine.
4. Equipment available
   (a) Airway equipment: portable oxygen (O_2) tank on side of isolette, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes,

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stylets, oral airway, suction with soft suction catheter, Mapleson, face mask, neonatal stethoscope
(b) Monitors: pulse oximeter, blood pressure (NIBP) cuff, 3-lead electrocardiogram (EKG), capnogram, temperature
(c) Lines: 24 gauge (G) and 22 gauge (G) peripheral intravenous (PIV) catheters, tourniquet, intravenous (IV) pigtail and flush, kit for umbilical venous catheter. No vein finder available. No ultrasound available.
(d) Paperwork: none.

Actors

1. Obstetrics/Gynecology (OB/GYN) circulator nurses
   (a) The nurses are a bit flustered because it's been a busy day on the Labor & Delivery Unit. One of the nurses is more senior and is training a new junior OB/GYN nurse. During the neonatal resuscitation, the OB/GYN nurse is having difficulty prioritizing resuscitating the baby and attending to the surgeon's needs.
2. Obstetrics/Gynecology (OB/GYN) surgeon
   (a) The OB/GYN surgeon is focused on caring for the mother. When the OB/GYN nurses realize something isn't right with the baby, the OB/GYN surgeon asks if the anesthesiologist can do anything to help until the neonatal intensive care unit (NICU) team arrives.
3. Mother
   (a) The mother is anxious. This is her firstborn child and she has had a healthy pregnancy. She was induced for failed induction of labor at 39 weeks due to pre-eclampsia, and she is disappointed that she had to have a cesarean section (C-section). Her c-section was done under spinal block.
4. Father
   (a) The father is supportive and eager to help. He keeps asking if there's anything wrong with mom or baby and if he can do anything.
5. Doula
   (a) The doula is attentive to the mother and is playing music to calm the mother. She continues to coach the mother through the c-section.

Case Narrative

1. Scenario background given to participants:
   (a) Setting: labor and delivery operating room in a community hospital across the street from a children's hospital.

(b) You are the anesthesiologist caring for a 27-year-old gravid 1 para 0 who just delivered a baby girl. The mother did not have regular prenatal care but says the baby looked fine on her ultrasound 3 months ago. She was admitted for regular contractions and taken to the operating room (OR) urgently for repeated fetal decelerations.

2. Scenario development

(a) Phase 1: neonatal respiratory distress

(i) The baby has just been delivered. The mother's anesthetic has proceeded without complication so far. Average blood loss. Spinal block working well. 30 minutes into the surgery.
(ii) The OB/GYN nurses bring the baby over to the isolette for observation and measurements, and notice that the baby seems to be struggling to breathe.
(iii) The OB/GYN nurses call for Neonatal Intensive Care Unit (NICU)/Pediatrics team STAT, but they are off-site at a different hospital and it will take them 10–15 minutes to arrive.
(iv) The OB/GYN nurses/surgeon ask if you as the anesthesiologist can do anything to help resuscitate the baby. The mother, father, and doula are anxious and repeatedly ask for updates about the baby, and ask if you know what you're doing since you're not a pediatric anesthesiologist.
(v) The learner must decide if / how to assist with the neonate, and if they are going to assist with the neonate, how will they continue to monitor the mother, who is their priority in the Labor and Delivery OR.
(vi) An option available to the learner is to wheel the isolette over from the back of the delivery room to the head of the bed where the mother is, and to ask the father and the doula to step back or to leave the room.
(vii) The learner should recognize signs of neonatal respiratory distress: grunting, tracheal tugging, sternal retractions.
(viii) The learner should ask the nurses to place monitors on the patient, including electrocardiogram (EKG), non-invasive blood pressure (NIBP) cuff, pulse oximeter (SpO_2) pre-ductal, and auscultate for breath sounds. Initial VS: EKG 110 bpm, BP 70/40, SpO_2 65%.
(ix) The learner should consider what is a normal SpO2 in a neonate by each minute of life. The learner should move to provide positive pressure assisted ventilation via bag valve mask.
(x) The OB/GYN nurse should ask the learner what they think might be going on and why the neonate might be in respiratory distress.

(b) Phase 2: decision to intubate

(i) The learner will apply a mask and Mapleson to the baby to deliver continuous positive airway pressure (CPAP).
(ii) The vital signs continue to worsen: EKG 70 bpm, BP 60/30, SpO2 40%.
(iii) The OB/GYN nurse in the scenario should not comment that the belly seems to be getting bigger and the saturation is not improving.

(iv) The learner should recognize that positive pressure ventilation via mask ventilation is ineffective and they should move to intubate.

(c) Phase 3: hypoglycemia

(i) The OB/GYN nurse should ask the learner if there's anything else they can do to evaluate for causes of respiratory distress. The learner should suggest further history, physical, labs including fingerstick glucose, chest radiograph (CXR), and echocardiogram to evaluate for syndromes such as cyanotic congenital heart disease.

(ii) The OB/GYN nurse will do a heel stick to send complete blood count (CBC), basic metabolic panel (BMP), and serum glucose, and report that the glucose is 25. The nurse will ask what should they give to treat the hypoglycemia, how should they administer (per oral (PO) or intravenously (IV)), and what the dosing is.

(iii) The learner may suggest placing a peripheral intravenous (PIV) line. The OB/GYN nurses will struggle to find an PIV and ultimately be unsuccessful.

(iv) The learner should recognize that the umbilical vein is available for cannulation, and should move to cannulate the umbilical vein and administer dextrose 25% at 2 cc/kg.

(v) If the learner does not think of umbilical venous cannulation themselves, the nurse may hint at it by commenting that there is a umbilical venous catheter (UVC) kit in the drawer of the neonatal resuscitation cart.

Scoring Rubric

Table 13.1 Scoring rubric for case scenario on Delivery Room Resuscitation

Topic: Delivery Room Resuscitation			
Participant name:			
Evaluator name:			
Score:			
		Completed	Not completed
Respiratory distress			
Communication	Inquires about availability of a pediatrician or neonatologist		
	Asks mother/father if it's ok that they try to help the baby		
	Brings the baby's isolette over to the head of the bed by mother to monitor mother while also caring for baby		
	Asks for neonatal resuscitation equipment (airway, vascular, medication)		
	Asks for assistance placing monitors on baby		

Table 13.1 (continued)

Evaluation	Observes for signs of respiratory distress (grunting, sternal retractions, tracheal tugging)		
	Auscultates for breath sounds		
	Identifies normal pulse oximeter (SpO_2) reading in a neonate based on minute of life		
Management	Provides continuous positive airway pressure (CPAP) via bag valve mask		
	Identifies worsening SpO_2, hypotension, and bradycardia		
	Initiates positive pressure ventilation via bag valve mask		
	Recognizes distended abdomen		
	Attempts to relieve distended abdomen by passing orogastric (OG) tube or applying gentle pressure to abdomen		
	Makes decision to intubate baby		
	Intubates baby in a timely fashion		
Hypoglycemia			
Evaluation	Asks about further history (complications during pregnancy and delivery, prenatal ultrasound, recent medications, infections)		
	Examines baby for signs of congenital malformations		
	Draws heel stick for labs (glucose)		
	Considers chest radiograph (CXR) and trans-thoracic echocardiogram, which may need to be done at a children's hospital later		
Management	Identifies hypoglycemia (serum glucose <30 in neonate)		
	Correctly identifies dose of dextrose to treat hypoglycemia: Dextrose 25% at 2 cc/kg		
	Asks for assistance establishing vascular access (peripheral intravenous versus umbilical venous catheter line)		
	Recognizes that umbilical venous catheter is first line choice for establishing venous access per neonatal resuscitation program (NRP) guidelines		

Summary of Clinical Teaching Points

As you're walking into a neonatal resuscitation, what do you want to ask?

- What is the estimated gestational age?
- How many babies are there?
- Are there any known congenital defects?

  - In-utero ultrasound
  - Genetic workup
- Are there any maternal co-morbidities?
- What are the current vitals and APGAR score?
  - Appearance
  - Pulse
  - Grimace
  - Activity
  - Respiration

What are the logistics of the obstetric anesthesiologist being asked to assist with a delivery room neonatal resuscitation?

- Worst case scenario: you're in an adult hospital with no pediatrician and no neonatologist in-house.
- Available help:
  - OB/GYN nurse
  - Potentially a pediatrician or neonatologist "locally" from an outside children's hospital
- Legally: as the obstetric anesthesiologist, your responsibility is the mother. Your patient is the mother.
- Caveat: you may be the most experienced medical provider in the room who has the skills to help resuscitate the neonate.

How can you set yourself up for success?

- The isolette that the neonate is in has wheels. Bring it over to you at the head of the operating room table. This way, you can keep an eye on mom and mom's monitors.
- Consider asking extra people to leave the room to minimize noise and distractions.
- Notify mom and/or dad of what you are doing. Check for permission to assist in the neonatal resuscitation of their baby.
- The isolette should have an oxygen tank on it. If it's not available, attach a Mapleson circuit to the auxiliary oxygen port on your ventilator and use that as your oxygen source.
- Follow standard operating room checklist:
  - Example: MOMSAID acronym
  - Machine: Mapleson and face mask, +/− oral airway
  - Oxygen: oxygen tank, auxiliary oxygen port from ventilator
  - Monitors: 3-lead electrocardiogram (may be hard to place on neonate due to fluids, wipe down with towel to create more adhesive surface), pulse oximeter, non-invasive blood pressure cuff

  - Suction: suction from ventilator
  - Airway: Miller 0 (term)/Miller 00 (pre-term) blades; various sized endotracheal tubes (2.0 uncuffed, 2.5 uncuffed, 3.0 cuffed, 3.0 uncuffed), stylet, oral airway, face mask, nasal cannula, nasal continuous positive airway pressure (nasal CPAP), Neo-Puff
  - Intravascular access: can be challenging in neonate; first line choice for venous access in neonatal resuscitation is umbilical venous catheter
  - Drugs: mostly resuscitation is an airway issue, with resolution of hypoxemia, hemodynamics generally improve. Consider preparation of code dose of epinephrine 10 mcg/kg intravenously.

What would you, as the obstetric anesthesiologist, be asked to assist with?

- If you're getting involved, you're probably headed down the route of airway intervention.
- What are signs of respiratory distress in a newborn?
  - Cyanosis
  - Grunting
  - Retractions of chest wall: subcostal, intercostal, and/or suprasternal
  - Nasal flaring
  - Tachypnea
  - Stridor
  - Wheezing
- Untreated hypoxemia and hypercarbia will eventually lead to bradycardia and then cardiac arrest

What should you do?

- Do what you know: ABCs. Airway. Breathing. Circulation.
- Support the patient's breathing with continuous positive airway pressure (CPAP) via a face mask and Mapleson.
- If the patient is not ventilating well (i.e. still low pulse oximetry reading, bradycardia, visibly working hard to breathe), try something new.
  - Check your face mask positioning: chin lift, jaw thrust, open mouth, avoid inadvertently compressing soft tissue with your fingers.
  - Insert an oral airway.
- If the patient is still not spontaneously ventilating well, move on to positive pressure ventilation.
  - Mask ventilation: but for how long? When can you let the baby breathe on their own again?
  - Intubation with an endotracheal tube: provides a secure airway and frees your hands for other tasks of the resuscitation.

- What if you can't intubate and can't ventilate?
  - Don't forget an LMA – size 1 for under 5 kg. It's not ideal, but it is a temporary way to reestablish oxygenation and ventilation until you can transfer them to a children's hospital and a more experienced pediatric anesthesiologist can intubate.

What are causes of cardiac arrest in a neonate?

Follow the typical H's and T's acronym used to evaluate causes of cardiac arrest in adults.

Table 13.2 Common causes of cardiac arrest in neonates using the "H" mnemonic

Cause by "H"	Diagnosis/Treatment
Hypoxemia Hypercarbia	Airway! Airway! Airway! Continuous positive airway pressure (CPAP) – Nasal, face mask Positive pressure ventilation (PPV) – Mask ventilation, intubation
Hypothermia	Actively warm – Blankets, overhead heater, warmed operating room
Hyperkalemia Hypokalemia	Heel stick labs – iSTAT machine vs. sendoff to lab
Hypoglycemia	Heel stick labs – Glucometer Glucose <30 → administer dextrose
Hypovolemia Hypotension Hydrogen ion (acidosis)	Heel stick labs Non-invasive blood pressure (NIBP) cuff readings Sodium bicarbonate not standard therapy anymore Consider fluid bolus 20 cc/kg

Table 13.3 Common causes of cardiac arrest in neonates using the "T" mnemonic

Cause by "T"	Diagnosis/Treatment
Trauma	Traumatic delivery
Toxins	Consider maternal history of drug use → opioid overdose in neonate → caution with naloxone → risk of seizures, intracranial hemorrhage
Tamponade	Low likelihood No bedside trans-thoracic echocardiogram available in delivery room
Tension pneumothorax	Possible – Traumatic delivery Auscultate breath sounds Consider needle decompression No bedside chest radiograph (CXR) in delivery room
Thrombosis	Cardiac = myocardial infarction – Low likelihood Pulmonary = pulmonary embolus – Low likelihood

What is the differential diagnosis for respiratory distress in a newborn? [1–3]

Table 13.4 Differential diagnosis for respiratory distress in a newborn by organ system and anatomy

System	Anatomy	Differential Diagnoses
Pulmonary	Nasopharynx	Obstruction – Nasal or airway secretions, congestion, choanal atresia, enlarged or redundant upper airway tissue
	Oropharynx	Upper airway obstruction – Macroglossia, micrognathia
	Larynx, glottis	Subglottic stenosis, obstruction, laryngomalacia, vocal cord paralysis, subglottic stenosis, vascular ring, papillomatosis, neck mass
	Tracheo-bronchial tree	Stenosis, obstruction, fistula (tracheo-esophageal fistula), tracheal atresia, tracheo-bronchial malacia
	Lung parenchyma	Intrinsic: Transient tachypnea of newborn, meconium aspiration syndrome, respiratory distress syndrome, congenital lung malformation or hypoplasia, pleural effusion, pneumothorax, cyst, bullae, congenital lobar emphysema, pulmonary alveolar proteinosis, surfactant protein deficiency, pneumonia Extrinsic: Congenital diaphragmatic hernia, enlarged heart, chest wall deformities or mass
Cardiovascular	Cardiac	Cyanotic and select acyanotic congenital heart disease, neonatal cardiomyopathy, pericardial effusion, cardiac tamponade, fetal arrhythmia, high output cardiac failure
	Pulmonary vascular system	Persistent pulmonary hypertension of newborn
Neurological	Iatrogenic/external	Anesthetics: Magnesium, general anesthesia Maternal drug use
	Brain	Intracranial hemorrhage, central apnea, obstructive apnea, birth trauma, hemorrhage, hypoxic-ischemic encephalopathy, cerebral malformations, chromosomal abnormalities, congenital TORCH infections, seizures, meningitis, hydrocephalus, arthrogryposis
	Neuromuscular	Neuromuscular disorders, myopathies, skeletal dysplasia, paralysis, myotonic dystrophy, spinal cord injury
Gastrointestinal Hepatic	Stomach, bowel, other abdominal organs	Omphalocele, gastroschisis, necrotizing enterocolitis, meconium aspiration syndrome
Renal Metabolic		Electrolyte derangements, metabolic disorders, hypothermia or hyperthermia, hydrops fetalis
Hematology Oncology		Anemia, polycythemia, hemolytic disease

How do you dose and administer neonatal medications? [1–3]

- In a neonatal resuscitation, an umbilical venous catheter (UVC) is the preferred route for emergency vascular access.
- Epinephrine
  - Code dose is 10 mcg/kg intravenous
  - Hypotension/bronchospasm: 1 mcg/kg intravenous
  - "Small dose:" 0.1 mcg/kg intravenous
- Succinylcholine 2 mg/kg intravenous or 4 mg/kg intramuscular
- Atropine 20 mcg/kg intravenous or 20 mcg/kg intramuscular (no longer a 100 mcg minimum dose)
- Rarely require naloxone, but dose is 10 mcg/kg intravenous
- Dextrose: for hypoglycemia (glucose <30). Dextrose 50% is too concentrate to administer to a neonate. Preference is to use dextrose 25% 0.5 g/kg = 2 cc/kg.

What are special considerations for placing an umbilical venous catheter (UVC)? [1–3]

- UVC is first-line for establishing IV access in a neonatal resuscitation
- Precautions/Contraindications:
  - Peritonitis
  - Necrotizing enterocolitis
  - Omphalitis
  - Omphalocele
  - UVC: portal venous hypertension
  - UAC (umbilical arterial catheter): evidence of local vascular compromise in lower limbs or buttocks
- Complications:
  - Infection
  - Hemorrhage – uncommon
  - Air embolism – potentially catastrophic
  - Thrombosis – more common with infusion of hypertonic fluids
  - Necrotizing enterocolitis – if obstruction to portal venous flow

How do you place an umbilical venous catheter (UVC)? [1–3]

- Supplies
  - Catheter – 3.5 Fr × 15 inch or 5.0 Fr × 15 inch
  - UVC tray
  - Normal saline flush

- Preparation of umbilical cord
  - Clean the umbilical cord with betadine or other antiseptic solution.
  - Tie the cord snugly but not tightly, in a simple knot, with umbilical tape from the UVC kit.
  - Cut the umbilical cord with a scalpel below the umbilical cord clamp to about 1–2 cm from the skin (ABOVE the tie).
- Insertion of catheter
  - Attach a 3-way stopcock from the tray to the catheter.
  - Flush the catheter with normal saline.
  - Insert the catheter to 2–3 cm (until blood is returned).
  - You may need to loosen the umbilical tie to advance the catheter. The tie is there for hemostasis.
- No time for sterile gown or time for sterile drapes during emergent placement in the delivery room. Goal is to place as quickly as possible. Neonatologist can remove and replace in more sterile/precise fashion later.
- Other tips and tricks for UVC insertion:
  - Ideal location of the tip of the UVC: beyond the ductus venosus, in the central venous system (inferior vena cava or right atrium)
  - Avoid leaving the UVC tip in the portal circulation

    Risk of localized infection
    Slower blood flow, so risk of thrombosis or damage from infusion of hypertonic solutions
    Inaccurate measure of central venous pressure (CVP)
- What can you give through the IVC?
  - Any medication
  - Any fluid
  - Emergency medications can be given below the liver and the UVC can later be repositioned when the patient is more stable and imaging is available.

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Chapter 14
Difficult Airway in Obstetrics (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss anesthetic options for emergency cesarean section.
2. Discuss anesthetic management of difficult airway in obstetrics.

Simulator Environment

1. Location: obstetrics operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 x 18 Gauge (G) peripheral intravenous (PIV) catheter, foley catheter, lumbar epidural catheter
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, 2% lidocaine, 3% chloroprocaine, 0.125% bupivacaine.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator
   (e) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy handing equipment to the obstetricians.
2. Circulator nurse
   (a) The nurse is busy helping to open trays.
3. Obstetricians
   (a) The obstetricians are busy scrubbing in and preparing to make incision for emergent cesarean section.

Scenario Development

1. Background
   (a) You are the anesthesiologist starting an emergent cesarean section for a 25-year-old G6P1, 39 weeks pregnant, breech presentation, body mask index (BMI) 60, whose baby is having decelerations not responsive to supportive measures (supplemental oxygen, fluid bolus, repositioning). She had a labor epidural which was difficult to place, and the patient reported that she had inadequate pain control in the last couple of hours.

2. Phase 1: non-functioning epidural

   (a) The patient is lying supine on the operating room table. The obstetrician has prepped the abdomen and is awaiting the signal from the anesthesiologist that it is okay to proceed with incision.
   (b) The learner will attempt to load the epidural with a fast-acting local anesthetic such as lidocaine or chloroprocaine. However, the patient will have completely intact strength and sensation and the epidural will be noted to be non-functioning.
   (c) The surgeon will continue to emphasize that they need to hurry and move quick to remove the baby, who is having worse decelerations.
   (d) The learner may attempt to troubleshoot the epidural such as pulling it back, tilting the bed Trendelenburg positioning, or checking the back. The epidural will be noted to have become dislodged. This patient is a very difficult neuraxial block due to her body habitus and there is no time to perform a neuraxial block.

3. Phase 2: general anesthesia – difficult intubation

   (a) The learner will move to general anesthesia with plan for endotracheal intubation. The learner should prepare for difficult intubation. The learner should try to maintain normal hemodynamics and perform a rapid sequence induction to minimize aspiration risk.
   (b) The learner will find that regardless of technique (direct laryngoscope, video laryngoscopy, or fiberoptic bronchoscopy), they are unable to intubate the patient and unable to mask ventilate.
   (c) Following the American Society for Anesthesiology Difficult Airway Algorithm, the learner should move to place an laryngeal mask airway (LMA), which will prove successful in re-establishing ventilation and oxygenation.
   (d) The learner should enable the obstetricians to proceed with incision with the LMA in place.
   (e) The learner can then try to establish a definitive airway using a fiberoptic bronchoscope through the LMA.

Scoring Rubric

Table 14.1 Scoring rubric for case scenario on Difficult Airway in Obstetrics

Topic: Difficult Airway in Obstetrics (Adult)			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Epidural assessment			
Assessment	Assesses level of sensory and motor blockade using ice/pinprick		
	Checks epidural level prior to re-dosing		
	May attempt to improve level of epidural blockade using a fast-acting local anesthetic: Lidocaine, chloroprocaine		
	May attempt to troubleshoot the epidural: Pulling it back, tilting the bed in Trendelenburg position, assessing depth of catheter at skin		
	Considers replacing epidural with new epidural or performing a spinal block		
	Discusses timing of replacement neuraxial blockade with obstetrician and considers potential harm to fetus of the delay		
	Recognizes that there is insufficient time to replace the epidural		
General anesthesia			
Induction	Does not induce until confirming that obstetrician is ready, patient is prepped and draped		
	Counsels patient that the plan is general anesthesia instead of monitored anesthesia care (MAC) under neuraxial blockade		
	Prepares equipment for difficult mask ventilation and difficult intubation: Blades and endotracheal tubes (ETTs) of various sizes, oral airway, nasal trumpet, video laryngoscope, fiberoptic bronchoscopy		
	Performs rapid sequence induction +/− cricoid pressure		
Difficult intubation	Recognizes difficult intubation and attempts to upgrade to difficult airway equipment		
	Recognizes difficult mask ventilation		
	Places laryngeal mask airway (LMA) and re-establishes ventilation and oxygenation		
	Discusses difficult airway with obstetrician and considers allowing obstetrician to proceed with cesarean section		
	May intubate with fiberoptic bronchoscopy through the LMA		

Summary of Clinical Teaching Points

What are your anesthetic options for an emergent cesarean section? [1–3]

Table 14.2 Comparing the pros and cons of monitored anesthesia care with neuraxial block versus general anesthesia with endotracheal intubation for an emergent cesarean section

	Monitored Anesthesia Care (MAC) with Neuraxial Blockade	General Anesthesia with Endotracheal Intubation
Pros	Mother is awake for birth of child Avoid risk of difficult intubation / difficult mask ventilation Avoid instrumenting the airway Minimize aspiration risk Minimize narcotic usage More stable hemodynamics Father of baby / support person can be present in the operating room	Secure airway, controlled ventilation, especially if there are other co-morbidities or risk of hemodynamic instability Easier to have secure airway when need to resuscitate patient – Crystalloids, colloids, blood transfusion, pressors, inotropes, trans-esophageal echocardiogram
Cons	Potentially time-consuming to place neuraxial block and wait for it to reach surgical level of dense motor and sensory block Further delay if block does not work and need to troubleshoot or redo the procedure Positioning: Ideally sitting for neuraxial block, but patient may be unstable or in so much pain that unable to sit in proper positioning	Risk of difficult intubation and difficult mask ventilation, resulting in loss of airway, inability to ventilate and oxygenate Risk of hemodynamic instability with induction and maintenance of general anesthesia Aspiration risk Mother not awake to witness birth of child Father of baby / support person typically not allowed in the operating room if mother is under general anesthesia

What is the management of a difficult airway in obstetric anesthesia? [4, 5]

1. Pre-induction team meeting with the surgeons, anesthesiologists, and nurses to plan and prepare for difficult airway management.
2. Rapid sequence induction due to high aspiration risk. Patient may require face mask ventilation in between repeat intubation attempts.
3. Laryngoscopy: limit the number of intubation attempts by each provider. Low threshold to move to more experienced provider if unsuccessful with initial intubation attempt.
   (a) Confirm successful tracheal intubation with objective markers: end-tidal carbon dioxide, fogging of endotracheal tube, bilateral chest rise, clear and equal bilateral breath sounds.
4. If failed intubation, call for help, notify fellow staff, re-establish oxygenation and ventilation using face mask ventilation or insertion of a supraglottic airway.
   (a) If you are able to re-establish oxygenation and ventilation using mask ventilation or a supraglottic airway, then decide…

(i) If it is essential to proceed with the surgery immediately, then proceed with surgery.
(ii) If it is not essential to proceed with the surgery immediately, then cancel the surgery and awaken the patient.

(b) If

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Chapter 15
Down Syndrome (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss risks of anesthesia in patients with Down syndrome.
2. Discuss pre-operative evaluation of patients with Down syndrome.
3. Discuss intraoperative precautions to take with Down syndrome.

Simulator Environment

1. Location: pre-operative area of an adult hospital
2. Manikin setup:
   (a) Age: adult
   (b) Lines: none at start of case
   (c) Monitors: none on patient at start of case
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, ketamine.
4. Equipment available

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(a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheatl tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
(b) Monitors: pulse oximeter, blood pressure cuff, 5-lead electrocardiogram (EKG).
(c) Lines: arterial line kit, central line kit, peripheral intravenous (PIV) kits
(d) Crash cart with defibrillator
(e) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy opening trays and making lots of noise.
2. Circulator nurse
   (a) The nurse is busy helping to open trays.
3. Surgeon
   (a) The surgeon is busy dictating the operating report from the previous patient.

Scenario Development

1. Background
   (a) You are the anesthesiologist starting the case of a 26-year-old boy with Down syndrome, severe developmental delay, history of large ventricular septal defect (VSD) status post repair in infancy, obesity, and obstructive sleep apnea (OSA) noncompliant with continuous positive airway pressure (CPAP) due to discomfort with face mask. He is scheduled to go to the OR for tonsillectomy and adenoidectomy.
2. Phase 1: patient refusal to leave the preoperative area, parent induction
   (a) In the preoperative area, the patient is calm and quiet, sitting comfortably in the gurney with warm blankets, with mom and dad at bedside. He had refused to allow the nurses to check his vital signs or to place a PIV.

(b) The parents ask the anesthesiologist if there is any way they can do the PIV asleep, since he is scared of needles and has been a difficult PIV placement in the past.
(c) The learner may offer to do a mask induction and place the PIV asleep, and may consider calling for difficult PIV equipment to be sent to the room ahead of time (e.g. ultrasound, vein finder).
(d) When it is time to leave for the operating room (OR), the patient refuses, starts crying, and refuses to let go of his mother.
(e) The parents ask the anesthesiologist if it is possible to do a parent induction. They have always done parent inductions in the past. It is their son's first time receiving surgery in an adult hospital.
(f) The learner may offer to do a parent induction. If they choose to do a parent induction, they should provide clear instructions for what to expect during a mask induction and make sure the parent will be calm and willing to leave when asked to do so.
(g) With a parent present, the patient will be calm and cooperative.

3. Phase 2: upper airway obstruction and bradycardia during induction

(a) During induction, the patient will develop significant upper airway obstruction making mask ventilating challenging.
(b) The parent will become anxious and ask what's wrong. The learner should provide reassurance to the parent that this is expected and under control. The learner should ask the parent to leave so they can focus on patient care.
(c) The learner may cautiously place airway adjuncts such as an oral airway or nasal trumpet to assist with mask ventilation, but recognize that the patient may be in stage 2 and develop laryngospasm.
(d) The learner may administer CPAP by closing the airway pressure release valve and holding pressure using the ventilator bag.
(e) The learner should try to establish IV access as soon as possible but avoid triggering laryngospasm during stage 2.
(f) The PIV placement will be challenging and require multiple attempts. During attempted PIV placement, the patient will become bradycardic.
(g) The learner should recognize the bradycardia and discontinue the nitrous oxide, decrease the sevoflurane, and take over ventilating the patient manually via bag valve mask with 100% fraction of inspired oxygen (FiO_2).
(h) A PIV will be placed and the learner will proceed with intubation uneventfully.

Scoring Rubric

Table 15.1 Scoring rubric for case scenario on Down Syndrome

Topic: Down Syndrome			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Pre-operative area			
Communication	Asks parents about history of previous anesthetics/inductions and what's worked well for patient in past		
	Counsels parents about pros/cons and sequence of events of parent induction		
	Prepares room with equipment for difficult peripheral intravenous (PIV) line placement (ultrasound, vein finder)		
Upper airway obstruction			
Evaluation and management	Creates calm, quiet, attentive environment during induction		
	Identifies severe upper airway obstruction		
	Double checks / repositions hands to optimize mask seal		
	Provides continuous positive airway pressure (CPAP) via circuit/mask		
	May cautiously place oral airway and/or nasal trumpet		
	Politely but firmly asks parent to leave so they can focus on patient care		
Difficult PIV and Bradycardia			
	Identifies bradycardia		
	Adjusts anesthetic: Switches to 100% fraction of inspired oxygen (FiO_2), decreases sevoflurane concentration		
	Takes over mask ventilation instead of allowing spontaneous ventilation		

Summary of Clinical Teaching Points

What are the chances that you will take care of a patient with Down Syndrome? [1, 2]

- Down Syndrome is the most prevalent genetic disorder worldwide: 1 in 800 live births; >350,000 people in the United States.
- It is associated with multiple congenital anomalies that can affect every major organ system.
- Risk factors: maternal age >35 years old; exposure to pesticides and electromagnetic fields; smoking; drinking alcohol; thyroid autoimmunity; exposure to radiation and anesthetic agents

What are the potential challenges to airway management in Down Syndrome patients? [1, 2]

Table 15.2 Potential challenges to airway management in Down Syndrome patients by upper and lower airway anatomy

Upper Airway	Lower Airway
Choanal atresia	Airway malacia
Microdontia	Short neck
Mandibular hypoplasia	Hypotonia
Adenotonsillar hypertrophy	Subglottic stenosis
Macroglossia, relative glossoptosis	Respiratory tract infections
Microcephaly	Small upper and lower airways
Sleep apnea	
Upper airway obstruction	
Obesity	
Midface hypoplasia	
Increased secretions	
Small nasopharynx	

Table 15.3 Potential airway complications and management techniques in Down Syndrome patients by intra-operative and post-operative periods

	Complications	Management
Intra-operative	Difficult intubation Difficult mask ventilation Bronchospasm Tracheal stenosis: Difficult to pass endotracheal tube	Prepare additional rescue airway equipment (video laryngoscope, flexible fiberoptic bronchoscope, intubating laryngeal mask airway, flexible Bougie, emergency surgical airway equipment) Consider downsizing endotracheal tube Ensure adequate cuff leak Awake extubation
Post-operative	Post-extubation respiratory distress, stridor, croup, bronchiolitis, cyanotic events, wheezing Airway obstruction	Longer post-anesthesia care unit stay or overnight admission

What are cardiac considerations when caring for Down Syndrome patients? [1, 2]

40–50% of patients with Down Syndrome have some type of congenital heart disease. The following table provides a cursory overview of common heart defects.

Table 15.4 Cardiac anesthetic considerations for Down Syndrome patients

System	Pathophysiology	Anesthetic Considerations
Cardiac – Acyanotic defects	Complete atrioventricular defect Ventricular septal defect Atrial septal defect	Avoid increases in pulmonary vascular resistance Avoid high systemic vascular resistance Use low fraction of inspired oxygen Avoid low end-tidal carbon dioxide Antibiotic prophylaxis
Cardiac – Cyanotic defects	Tetralogy of Fallot	Normal to increased fraction of inspired oxygen Maintain normal pH Keep end-tidal carbon dioxide normal to low Keep systemic vascular resistance within normal limits Early treatment of intraoperative "Tet spell:" fluid bolus starting 10–20 cc/kg, phenylephrine 1 mcg/kg, oxygen
Rhythm anomalies	Conduction disturbances after repair of atrio-ventricular canal defect, tetralogy of Fallot, ventricular septal defect, transposition of the great arteries	Detect bradycardia quickly Increase fraction of inspired oxygen Caution with volatile anesthetic
Pulmonary vasculature	Pulmonary hypertension Eisenmenger syndrome (associated with obstructive sleep apnea and pulmonary hypoplasia)	Avoid exacerbating pulmonary hypertension (avoid hypoxemia, hypercarbia, and acidosis)

What are the indications for spontaneous bacterial endocarditis (SBE) prophylaxis? [1, 2]

- Dental surgeries or other "dirty" surgeries (not for all routine Urology cases).
- Prosthetic cardiac valve or prosthetic material used for cardiac valve repair.
- Prior infective endocarditis.
- Congenital heart disease:
  - Unrepaired cyanotic congenital heart disease, including palliative shunts and conduits.
  - Completely repaired congenital heart disease with prosthetic material or device, whether by surgery or catheter intervention, that were repaired within the last 6 months.
  - Repaired congenital heart disease with residual defects at the site or adjacent to the site of prosthetic patch or prosthetic device (which inhibit endothelialization).
- Cardiac transplant recipients who develop cardiac valvulopathy.

What are neurologic and musculoskeletal considerations for patients with Down Syndrome? [1, 2]

- Atlanto-occipital instability
  - 20% incidence
  - Ligamentous laxity of atlanto-axial joint → C1-C2 subluxation → spinal cord injury
- Minimize degree of neck flexion, extension, and rotation, especially during intubation
- Careful intraoperative positioning
- Review neck radiographs pre-operatively, where indicated
  - Not routinely done
  - Symptoms that should raise concern for possible cervical spine instability and prompt imaging pre-operatively: neck pain, gait disturbances, hand dysfunction, dizziness, bowel/bladder dysfunction, weakness, paresthesias, pain with neck flexion and extension, hyperactive distal tendon reflexes, ankle clonus, muscle weakness, increased muscle tone, neck discomfort, abnormal gait, difficulty walking, excessive laxity of other joints (fingers, elbows, knees)
- Consider using cervical collar intraoperatively if there is demonstrated cervical spine instability

What are gastrointestinal considerations for patients with Down Syndrome? [1, 2]

Table 15.5 Other anesthetic considerations for patients with Down Syndrome by organ system

System	Feature
Neurologic	Significant hearing loss and eye and vision problems Generalized hypotonia and joint laxity Cognitively challenged children can be harder to manage during induction – Consider parental presence
Immune	Some degree of immune dysfunction → affects cellular and humoral immunity → increased rate of infection Chronic sinus and ear infections
Endocrine	Thyroid hypofunction Diabetes mellitus
Hematologic	Polycythemia – May need phlebotomy to relieve circulatory failure
Gastrointestinal Renal	Umbilical hernia Renal malformations Undescended testes, hypospadias
Vascular	Radial artery abnormalities Makes percutaneous cannulation challenging

- High risk of gastroesophageal reflux disease (GERD)
  - Vomiting
  - Esophagitis (chest pain, anemia, irritability)
  - Respiratory: apnea, coughing, wheezing, aspiration pneumonia
- Common associated congenital defects
  - Duodenal atresia
  - Tracheo-esophageal fistula
  - Hirschsprung disease
  - Imperforate anus
- Consider rapid sequence induction where indicated

What are other systemic considerations for patients with Down Syndrome? [1, 2]

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Chapter 16
Hematoma Post-Thyroidectomy (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Review differential diagnoses for respiratory distress immediately post-extubation.
2. Review differential diagnoses for respiratory distress in the post-anesthesia care unit (PACU).
3. Review causes of airway compromise post-thyroidectomy.
4. Discuss management of emergent, difficult airway in the PACU.

Simulator Environment

1. Location: PACU of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 x 18 Gauge (G) peripheral intravenous (PIV) catheter
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter

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3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, racemic epinephrine.
4. Equipment available
   (a) Airway equipment: Mapleson, Ambu bag, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator

Actors

1. PACU nurse
2. Family member
   (a) The family member at bedside is anxious and repeatedly asking for updates. They want to know where the surgeon is and question whether the anesthesiologist knows what they are doing.

Scenario development

1. Background
   (a) You are the board runner covering the PACU, and the PACU nurse pages you STAT to bedside to evaluate a patient in respiratory distress.
   (b) Upon arrival, you see a 65-year-old woman, obese, who is sitting upright in bed, struggling to breathe on a simple face mask at 10 L/min, oxygen saturation (SpO_2) 88%. She is hypertensive and tachycardic. The gauze taped over her anterior neck is soaked through with bright red blood.
2. Phase 1: evaluation of respiratory distress in PACU
   (a) The learner should recheck vitals and perform a history and physical exam.
   (b) On exam, they will observe that the patient is using accessory muscles of respiration and is hyperventilating with shallow tidal volumes.
   (c) The patient is unable to speak due to severe respiratory distress. They point to their neck gesturing that they are suffocating.
   (d) From the history from the nurse, the learner will discover that this is a 65 yo woman with obstructive sleep apnea (OSA), hypertension (HTN), type 2

diabetes mellitus (T2DM), obesity with body mass index (BMI) 43, and goiter, who recently underwent an uneventful thyroidectomy. In the operating room (OR), she was an easy mask ventilation and easy intubation. She had some coughing and bucking at emergence, but otherwise tolerated extubation fine.

(e) She had been in the PACU for about 1 hour. She had some pain at the incision site and was given fentanyl. Then she felt nauseous and started dry heaving. Within about 30 minutes, she had increasing respiratory distress, was less talkative, and started desaturating. The nurse noted that her surgical site dressing appears much more bloody than when she first arrived to PACU.

(f) The learner should recognize that the patient has a rapidly expanding hematoma that will likely require drainage and control of hemostasis.

3. Phase 2: management of hematoma

   (a) The learner should try to contact the surgeon, who they will find is unavailable because they have already left the hospital. The surgeon will report that there was minimal bleeding intraoperatively so they are surprised that it is bleeding so much. They will return to the hospital but are currently stuck in evening traffic.

4. Phase 3: intubation and hematoma evacuation

   (a) The patient will eventually fatigue and become apneic. The learner should move to intubate the patient immediately.
   (b) The learner will find that they have a grade 4 view with direct laryngoscopy.
   (c) The learner may call for difficult airway equipment including a video laryngoscope. They will be unable to mask ventilate.
   (d) The learner may place an LMA. The fiberoptic bronchoscope will not be available.
   (e) The learner may consider cutting the neck to drain the hematoma and alleviate pressure and mass compression. This will result in lots of blood everywhere on the patient's gown and bed.
   (f) On repeat direct laryngoscopy, the learner will have an improved view and be able to intubate.

5. Phase 4: hemostasis

   (a) With the airway secured and adequate ventilation and oxygenation now resumed, the learner should try to obtain hemostasis. This may include applying and holding pressure manually or trying to apply a pressure bandage, until the surgeon arrives.
   (b) Depending on hemodynamics, labs, and the state of the bleeding, the learner may initiate massive transfusion protocol or at least order crossmatched blood.

Scoring Rubric

Table 16.1 Scoring rubric for case scenario on Hematoma Post-Thyroidectomy

Topic: Hematoma Post-Thyroidectomy			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Respiratory distress			
Evaluation	Rechecks vital signs		
	Obtains history (intraoperative complications, recent medication administration)		
	Auscultates bilateral breath sounds		
	Observes patient's work of breathing (accessory muscles, depth of tidal volumes, tracheal tugging, speech)		
	Examines surgical site. May remove dressing		
	Asks about post-surgical bleeding		
	Identifies expanding neck hematoma		
Management	Calls for emergency airway equipment (anesthesia cart, code bag, crash cart)		
	Calls for ear/nose/throat (ENT) surgeon to come to bedside STAT		
	Provides supplemental oxygen: Simple face mask, mask and Mapleson or Ambu-bag		
	Identifies patient is becoming fatigued		
	Decides to reintubate patient		
	Calls for equipment to release surgical sutures and hematoma		
	Calls for suction		
	Reintubates patient in a timely fashion.		
	Requests OR be prepared for emergent takeback for hemostasis		
Difficult intubation			
	Calls for difficult airway equipment (video laryngoscope, laryngeal mask airway, Bougie, Fiberoptic bronchoscope)		
	Recognizes inability to mask ventilate and inability to intubate		
	Follows difficult airway algorithm		
	Places laryngeal mask airway		
	Releases surgical sutures prior to intubation		
	Releases surgical sutures after failed intubation/mask ventilation		
	Performs repeat intubation attempt and is successful		
Hemostasis			
	Applies pressure manually or with pressure dressing		
	Checks venous blood gas (VBG) or arterial blood gas (ABG) to evaluate hemoglobin (Hb)/hematocrit (Hct)		
	Orders packed red blood cells (PRBCs) and fresh frozen plasma (FFP) to be crossmatched		
	May initiate massive transfusion protocol		

Summary of Clinical Teaching Points

What are common post-extubation complications in pediatric patients?

Table 16.2 Common causes of pediatric post-extubation complications

Event	Cause	Prevention and Treatment
Upper airway obstruction	Excessive narcotics Obstructive sleep apnea	Larger adolescent: Reposition to head of bed elevated Smaller: Reposition to lateral decubitus position with head extension
Laryngospasm	Deep extubation / laryngeal mask airway (LMA) removal Secretions Stage 2 emergence/extubation	Ensure adequate ventilation prior to leaving the operating room Minimize secretions by thoroughly suctioning Minimize head/neck manipulation post-extubation
Stridor	Airway edema Traumatic intubation Nerve injury	Early recognition Intravenous dexamethasone Racemic epinephrine Head of bed elevation
Bronchospasm	Recent upper respiratory infection Known asthma	Albuterol nebulizer Intravenous epinephrine

What are common causes of airway compromise post-thyroidectomy? [1–3]

Table 16.3 Common causes of airway compromise post-thyroidectomy based on time since surgery

Time Since Extubation	Type of Problem	Etiology	Special Considerations
Minutes-hours	Hematoma	Inadequate surgical hemostasis Coughing/bucking especially at emergence	Ecchymosis Bleeding at suture site/dressing Visually expanding neck
	Recurrent laryngeal nerve injury	Ischemia, contusion, traction, entrapment, transection	Unilateral vocal cord paralysis: Glottic incompetence, hoarseness, breathlessness, ineffective cough, aspiration Bilateral vocal cord paralysis: Stridor at extubation, requires reintubation
	Tracheomalacia	Prolonged compression of trachea by mass (e.g. goiter)	
	Laryngeal edema	Trauma Venous obstruction from large hematoma Generalized myxedema of hypothyroidism Thyroid lymphoma	
Hours-days	Hypocalcemia	Permanent: Inadvertent excision of parathyroids Transient: Reversible ischemia or edema	
	Wound infection		

What are risk factors for hematoma post-thyroidectomy? [1–3]

- Male gender
- Inflammatory thyroid conditions
- Partial thyroidectomy
- Kidney disease
- Bleeding disorders
- Previous thyroid surgery
- Less common in recent years with improved surgical instruments – thyroidectomy is typically an outpatient surgery

What are signs and symptoms of a hematoma post-thyroidectomy? [1–3]

- Prominent, dark ecchymosis
  - Present in 75% of cases of superficial bleeding
  - Present in 33% of cases of deep bleeding

- Respiratory distress
  - Present in a third of patients with deep hematoma
  - Less common with superficial hematoma

What do you do if you can't intubate and can't ventilate in a patient with a post-thyroidectomy hematoma? [1–3]

- Mass effect from the neck hematoma:
  - Distorted airway anatomy
  - Direct compression of the (expanding) hematoma on the larynx and pharynx
  - The later intubation is done, the more challenging it will be because of evolving hematoma expansion and compression.
- Laryngo-pharyngeal edema secondary to impeded venous and lymphatic drainage
- Prefer early re-intubation
  - Rare to require reopening of surgical wound to facilitate intubation
  - May need a smaller diameter endotracheal tube secondary to laryngeal edema

How do you release a neck hematoma post-thyroidectomy? [1–3]

- "Release the sutures."
  - Not always that simple
  - Need to release ALL the layers, not just the superficial sutures
  - Variables: superficial versus deep hematomas, bleeding location
  - Traditionally, clip removers are kept at bedside to be used to cut sutures and provide rapid release of hematoma
- Evacuation of hematoma
  - Irrigation
  - Manual removal by hand
  - Repeat surgery (e.g. take back to operating room) for hemorrhage is rare

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Chapter 17
Hemothorax (Adult)

Claire Sampankanpanich Soria and Suraj Trivedi

Case Outline

Learning Objectives

1. Identify signs and symptoms of hemothorax and pneumothorax.
2. Understand the steps to performing chest tube placement.
3. Review how to maintain a pleura-vac system.

Simulator Environment

1. Location: operating room of an adult hospital
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 2 x large bore peripheral intravenous (PIV) catheters
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide ($ETCO_2$)
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, vasopressin infusion, norepinephrine infusion.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG, radial arterial line.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator
   (e) Chest tube kit
   (f) Paperwork: pre-operative anesthesia history and physical

Actors

1. Surgeon
2. Circulating nurse

Scenario Development

1. Background
   (a) You are the anesthesiologist taking care of a 19-year-old man status post motor vehicle collision with a positive Focused Assessment with Sonography in Trauma (FAST) exam. The patient is rushed directly from the ambulance bay to the operating room with massive splenic injury
2. Phase 1: massive transfusion
   (a) The patient is severely hypotensive and tachycardic.
   (b) The learner should do the following:
      (i) Recognize massive blood loss due to abdominal bleeding.
      (ii) Initiate massive transfusion protocol.
      (iii) Establish large bore PIV access +/− central line.
      (iv) Administer fluid bolus (crystalloids and/or colloids) prior to induction.
      (v) Perform rapid sequence induction and intubation.
      (vi) Transfuse packed red blood cells (PRBCs), fresh frozen plasma (FFP), +/− platelets in balanced ratio.
      (vii) Place arterial line.
      (viii) Check complete blood count (CBC), coagulation studies, arterial blood gas (ABG).

(ix) Consider trans-thoracic echocardiogram (TTE) or trans-esophageal echocardiogram (TEE).
(x) Communicate with surgeon about ongoing blood loss and hemostasis.

3. Phase 2: hemothorax/pneumothorax

(a) Despite adequate fluid resuscitation and massive transfusion, the patient remains hypotensive and tachycardic.
(b) The peak pressure and plateau pressures will increase. The patient will progressively desaturate.
(c) The learner should perform the following:

(i) Use inotropes and/or vasopressors to manage hypotension.
(ii) Identifies signs of hemothorax/pneumothorax: elevated peak pressures, decreased compliance when ventilating, hemodynamic instability, diminished breath sounds.
(iii) Communicates with surgeon regarding suspicion for undiagnosed hemothorax/pneumothorax.
(iv) May relieve tension pneumothorax by performing needle decompression with 14 Gauge (G) needle while awaiting definitive chest tube placement.

Scoring Rubric

Table 17.1 Scoring rubric for case scenario on Hemothorax/Pneumothorax

Topic: Hemothorax/Pneumothorax (Adult)		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Massive transfusion		
Recognizes massive blood loss due to intra-abdominal bleeding		
Initiates massive transfusion protocol		
Establishes large bore peripheral intravenous line (PIV) access +/− central line		
Administers fluid bolus (crystalloids and/or colloids) prior to induction		
Performs rapid sequence induction and intubation		
Transfuses packed red blood cells (PRBCs), fresh frozen plasma (FFP), +/− platelets in balanced ratio		

(continued)

Table 17.1 (continued)

Places arterial line		
Checks complete blood count, coagulation studies, arterial blood gas		
Considers performing trans-thoracic echocardiogram or trans-esophageal echocardiogram		
Communicates with surgeon about ongoing blood loss and hemostasis		
Hemothorax/pneumothorax		
Uses inotropes and/or vasopressors to manage hypotension		
Identifies signs of hemothorax/pneumothorax: Elevated peak pressures, decreased compliance when ventilating, hemodynamic instability, diminished breath sounds		
Checks ventilator/circuit/endotracheal tube/surgical field/ breath sounds to assess compliance and identify etiology of elevated peak pressure		
Communicates with surgeon regarding suspicion for undiagnosed hemothorax/pneumothorax		
May perform needle decompression with 14 gauge catheter while awaiting definitive chest tube placement		

Summary of Clinical Teaching Points

What is a hemothorax? What is a pneumothorax?

- A hemothorax/pneumothorax is defined as the presence of blood (hemo-) or air/gas (pneumo-) in the pleural space between the parietal and visceral pleura which can result in impaired oxygenation.
- A large hemothorax or pneumothorax can result in a mediastinal shift with compromised hemodynamic instability.
- A pneumothorax can be spontaneous: primary (no disease) or secondary (underlying lung disease), versus traumatic (iatrogenic or non-iatrogenic).
- Hemothorax is defined as pleural fluid with a hematocrit greater than 50% [1].

What are common causes of spontaneous pneumothorax?

Table 17.2 Common causes of spontaneous pneumothorax [2]

Primary Spontaneous	Secondary Spontaneous
Subpleural blebs (associated with connective tissue disorders) Smoking Genetic predisposition	Chronic obstructive pulmonary disease (COPD) Cystic fibrosis Malignancy Infection Anatomical abnormalities of the pleural membrane

What are common causes of traumatic pneumothorax?

Table 17.3 Common causes of traumatic pneumothorax [2]

Iatrogenic	Non-iatrogenic
Central line insertion Thoracentesis Mechanical ventilation Pacemaker insertion Mediastinal biopsy Shoulder arthroscopy Not a comprehensive list. Many possible iatrogenic causes	External trauma (penetrating chest wound) Air travel and scuba

What are common causes of hemothorax?

- Most causes of hemothorax are caused by trauma, coagulopathy, malignancy, vascular malformations, or iatrogenic medical procedures
- Vascular: arterio-venous malformation, aneurysm, connective tissue disease
- Malignancy: angiosarcoma, thymoma, vascular tumors, lung cancer [3]

What are signs and symptoms of a pneumothorax or hemothorax?

- Usually patients present with tachycardia, sudden onset of shortness of breath, and decreased oxygen saturation.
- If there is mediastinal compression with tracheal deviation, hemodynamic compromise can be observed.
- On physical exam: distant or absent breath sounds, asymmetric lung expansion, tracheal deviation, hyper-resonance on percussion (in the case of a pneumothorax), jugular venous distension, pulsus paradoxus [3].
  - Hamman sign: pre-cordial crunching noises synchronous with the heartbeat

How can a pneumothorax or hemothorax be diagnosed on imaging?

- On chest radiograph (CXR), a pneumothorax appears as air without lung markings in the least dependent part of the chest. Air is found peripheral to the white line of the pleura. In an upright film, this is most likely seen in the apices.
- A pneumothorax is best demonstrated by an expiration film. It can be difficult to see when the patient is in the supine position. In the supine position, air rises to the medial aspect of the lung and may be seen as a lucency along the mediastinum. It may also collect in the inferior sulci, causing a deep sulcus sign [4].
- A hemo-pneumothorax is characterized by an air-fluid level on an upright or decubitus film in a patient with a pneumothorax [5].
- Computed tomography (CT) of the thorax is the gold standard, but is not available in the operating room.
- Chest radiograph can be readily available in the operating room, depending on the hospital resources. It can be also be done using a fluoroscopy machine borrowed from the orthopedic surgery room.
- Ultrasound is quick and easy to use in the operating room.

What is the management of a pneumothorax or hemothorax?

- In the setting of hemodynamic instability in the operating room, it is important to relieve the tension or drain the fluid as soon as possible. This can be done by needle decompression or chest tube placement.
- Administer 100% fraction of inspired oxygen (FiO_2) to help pleural air to reabsorb.
- Consider advanced monitoring such as an arterial line in cases of trauma with blood loss and need for accurate hemodynamic monitoring.
- Small bore tubes are standard treatment for moderate-sized pneumothorax [6].
- Hemothorax almost always will require a surgical chest tube.

How do you insert a chest tube?

1. Identify landmarks – fifth intercostal space at midaxillary line. May scan the area with ultrasound to ensure that diaphragm is not crossed.
   (a) Consider insertion at the fourth intercostal space in patients who are obese, short, pregnant, or have large ascites from cirrhosis.
2. Gather supplies:
   (a) Sterile personal protective equipment including gown, gloves, scrub cap.
   (b) Chest tube tray: 36–38 Fr size pneumothorax for hemothorax, 24–32 Fr size chest tube for pneumothorax, pleurivac system, scalpel, Kelly hemostats x 2, xeroform, gauze, lidocaine with 25% needle and syringe.
3. Explain to the patient the procedure. Place on full monitors including blood pressure, electrocardiogram, and pulse oximetry. Consider administering intravenous fentanyl or midazolam.
4. Abduct the patient's arm with the elbow flexed. Clean the area in usual sterile fashion and anesthetize site with lidocaine local anesthetic. Consider an intercostal nerve block. Be sure the pleura is well anesthetized as this is the most painful region.
5. Over the fifth rib, make an incision and use Kelly clamps to dissect through the space, up and over the top of the rib. Avoid the neurovascular bundle that runs along the inferior part of the rib.
6. Puncture through the pleura, holding the Kelly clamp in a controlled manner. Once through the pleura, open the clamp to spread the tissue. Leave your finger in the hole to ensure the space is not lost.
7. Pass the chest tube, which should be clamped distally and proximally, over your finger and into the space. Advance the chest tube until all the holes are within the thoracic cavity.
8. Secure the chest tube to the skin with suture. Wrap xeroform gauze around the edges to ensure an airtight seal between the skin and chest tube. Attach to the pleuravac system [7].

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Chapter 18
Laryngospasm (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Identify causes of apnea during inhalational induction.
2. Recognize signs of laryngospasm.
3. Discuss management of laryngospasm.
4. Discuss management of difficult peripheral intravenous (PIV) catheter placement.

Simulator Environment

1. Location: operating room in an adult hospital
2. Manikin setup:
   (a) Age: infant
   (b) Lines: none at start of case
   (c) Monitors: none on patient at start of case
3. Medications available: normal saline, propofol, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 3-lead electrocardiogram (EKG), capnogram, temperature
   (c) Lines: 24 Gauge (G) and 22 G PIV catheters, intraosseous kit, tourniquet, intravenous (IV) pigtail and flush. No ultrasound available. No vein finder available.
   (d) Crash cart with defibrillator
   (e) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The **scrub tech** is busy opening trays and making lots of noises in the background during induction. They are not paying attention and do not notice the anesthesiologist struggling or the monitors alarming. When asked for help, they shrug their shoulders and say they don't usually do pediatrics.
2. Circulator nurse
   (a) The nurse normally takes care of adults and has never worked in a children's hospital. They don't notice you are starting induction and are busy counting instruments when you start your induction. They have never put an IV in a child before but are excited for you to teach them. They noticeably fumble with the equipment.
3. Surgeon
   (a) The surgeon is on the phone at the computer dictating their operative note from a previous patient.
4. Medical student on anesthesia rotation
   (a) The medical student is a fourth-year applying to psychiatry and is not sure what to do on the rotation. They struggle to restrain the child during induction, so the baby keeps twisting and turning and almost rolls off the table.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist starting a case of a 9-month-old, 10 kilogram (kg) baby boy here for circumcision.
   (b) Preoperative history: ex-full term; healthy; no recent URI symptoms; eating and growing well, meeting all developmental milestones; last ate breast milk 4 hours ago.
   (c) Preoperative physical: well-nourished baby sleeping in his mother's arms under a blanket; per parents, a few baby teeth are coming out but nothing loose; breath sounds clear to auscultation bilaterally.
   (d) Preoperative vital signs: none
   (e) Preoperative labs: none.
2. Scenario development
   (a) Phase 1: disorganized inhalational induction and laryngospasm
      (i) Inhalational induction is started. No one in the room is paying attention or helping the anesthesiologist.
      (ii) The learner should call for quiet and attention during induction; ask for assistance holding the patient's arms and legs during induction; ask for assistance placing monitors; ask for assistance placing a PIV while they hold the mask.
      (iii) Patient is going through stage 2 during induction and is about to roll off the table.
      (iv) The circulator nurse asks if now is a good time to start the PIV and she struggles and is unsuccessful with the PIV placement.
      (v) The medical student notes that the patient looks blue.
      (vi) The heart rate and oxygen saturation drop rapidly.
      (vii) Vital signs: apnea, respiratory rate (RR): 0, no end-tidal carbon dioxide ($ETCO_2$) on capnogram, heart rate (HR) 60, oxygen saturation (SpO_2) 60%, blood pressure (BP) 80/40.
      (viii) The learner should recognize bradycardia, hypotension, and desaturation secondary to inadequate ventilation/oxygenation.
   (b) Phase 2: attempts to break laryngospasm mechanically and pharmacologically
      (i) The learner should recognize laryngospasm and attempt to break it with 100% fraction of inspired oxygen (FiO_2), 8% sevoflurane, and positive pressure ventilation.
      (ii) Positive pressure ventilation via bag-mask ventilation is attempted while nurse and medical student try to place PIV.

(iii) Poor seal with mask and difficult mask ventilation. Anesthesiologist attempts additional maneuvers: oral airway, nasal trumpet, two-handed mask ventilation, jaw thrust, chin lift, but is unsuccessful.
(iv) A PIV still has not been placed because patient is a chubby infant. The learner must recognize difficult PIV placement and that they need to place the PIV themselves.
(v) The learner may ask the nurse or medical student to mask the patient while they try to place a PIV. Neither circulator nurse nor medical student knows how to mask the infant and the child continues to worsen – further desaturation and bradycardia and hypotension.
(vi) The learner must recognize they do not have time to place a PIV and must re-establish ventilation first. The learner should administer succinylcholine 4 mg/kg intramuscular (IM).
(vii) Laryngospasm breaks and anesthesiologist is now able to mask ventilate easily.
(viii) There is still no PIV.
(ix) The learner should secure the airway by LMA or ETT.
(x) May call for help.
(xi) Vital signs: HR 90, SpO2 99%, BP 90/50.

(c) Phase 3: difficult PIV placement and anesthetic overdose

(i) The learner is unable to find a vein after multiple failed attempts at all visible veins by the medical student and circulator RN.
(ii) The learner may call for an ultrasound but the regional team is using it, so it won't be available for at least 15 minutes.
(iii) The learner may call for a vein finder, but it's broken.
(iv) Vital signs: HR 40, SpO2 89%, BP 50/30.
(v) While working on a PIV, the learner realizes that the medical student accidentally left the sevoflurane canister at 8% from induction, resulting in anesthetic overdose and myocardial depression.
(vi) The learner should call for an intraosseous kit and establish intraosseous (IO) access while the circulator nurse or medical student begins chest compressions.
(vii) The learner should resuscitate the patient with epinephrine 10 mcg/kg and fluid bolus 20 cc/kg.
(viii) Vital signs: HR 100, SpO2 95%, BP 90/50.

Scoring Rubric

Table 18.1 Scoring rubric for case scenario on Infant Induction/Laryngospasm

Topic: Infant Induction Laryngospasm			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Inhalational induction			
Communication	Calls for quiet and attention in the room		
	Asks for assistance restraining patient		
	Asks for assistance placing monitors after patient enters stage 1 of anesthesia		
PIV placement	Recognizes when patient is in stage 2 vs. stage 3 of anesthesia		
	Identifies safe time for assistant to attempt peripheral intravenous (PIV) catheter placement		
Laryngospasm			
Evaluation	Identifies inadequate oxygenation and ventilation		
	Identifies bradycardia and hypotension		
	Recognizes that the hypotension and bradycardia are due to respiratory arrest		
	Correctly identifies laryngospasm as etiology of apnea		
Management	Administers positive pressure breaths with 100% fraction of inspired oxygen (FiO_2) and 8% sevoflurane		
	Ensures adequate face mask seal		
	Attempts assistive maneuvers: Oral airway, nasal trumpet, two-handed mask ventilation, jaw thrust, chin lift, 2-handed mask ventilation		
	Recognizes that unable to break laryngospasm with positive pressure ventilation		
	Recognizes that assistants are still unable to establish PIV access		
	Administers muscle relaxant via intramuscular route: Succinylcholine 4 mg/kg or rocuronium 1.2 mg/kg		
	Reestablishes ventilation after paralytic.		
	Secures the airway by LMA placement or intubation in order to free their hands for PIV placement		

(continued)

Table 18.1 (continued)

Difficult IV access			
Evaluation	Identifies that patient is a difficult PIV		
	Calls for assistance with PIV		
	Calls for difficult intravascular (IV) line equipment: Ultrasound, vein finder, central line kit, intraosseous kit		
	Recognizes multiple failed PIV attempts and worsening bradycardia/hypotension		
Management	Makes timely decision to place intraosseous line		
	Places intraosseous line correctly		
Cardiac arrest			
Evaluation	Recognizes initial hypotension and bradycardia was secondary to respiratory arrest		
	Recognizes worsening hypotension and bradycardia are due to unintentional anesthetic overdose		
	Recognizes anesthetic overdose		
Management	Discontinues sevoflurane		
	Directs assistant to initiate chest compressions		
	Administers code dose of epinephrine 10 mcg/kg		
	Administers fluid bolus of crystalloid 20 cc/kg		

Summary of Clinical Teaching Points

How do you maintain vigilance during induction?

- Watch your patient, not your monitor.
  - If their chest is moving, they're ventilating.
  - If they're pink and you're on 100% fraction of inspired oxygen (FiO_2), your oxygen partial pressure (P_aO_2) is 300 s–400 s mmHg, excluding congenital heart disease.
  - Usually, monitors will be placed during induction.
  - Monitor your patient's progression carefully from stage 1 to stage 2 to stage 3 of anesthesia.
- Raise awareness of pediatric induction, especially if it's an inhalational induction with no secure airway and no intravascular access yet established.
  - Ask for quiet – tone down the music, conversations, and equipment noises.
  - Ask the circulator nurse or other assistant to help calm the child, distract them, and hold their arms and legs.

What happens in the Guedel's stages of anesthesia? [1–4]

Table 18.2 Characteristics of Gudele's stages of anesthesia

Stage of Anesthesia	Definition	Respiratory Characteristics	Neurologic Characteristics	Hemodynamic Characteristics
Stage 1: Amnesia and analgesia	From beginning of anesthesia to loss of consciousness	Breathing with chest wall Tidal volumes 8–10 cc/kg	Conjugate gaze Purposeful movements	
Stage 2: Excitement	From loss of consciousness to onset of regular pattern of breathing	Paradoxical breathing / see-saw pattern: On inhalation, abdomen rises and chest falls; on exhalation, abdomen falls and chest rises Increase in respiratory rate, irregular respiration Highest risk of laryngospasm – Be very cautious with stimulation	Disconjugate gaze, pupils dilated and reactive to light Non-purposeful movements, uninhibited reaction Increased muscle tone	Increase in heart rate
Stage 3: Surgical anesthesia	From onset of regular pattern of breathing to cessation of respiration	Breathing with abdomen Tidal volumes 3–5 cc/kg	Relaxed muscle tone	
Stage 4: Respiratory paralysis, cardiac failure, death	From time of cessation of respiration to failure of circulation	Cessation of respiration: Not to be confused with apnea of breath-holding		Pre-mortem – Unintentional

How do you know if your patient is breathing, and how might you be wrong?

Table 18.3 Common signs of breathing confirmation and sources of confusion

Signs of Breathing	Sources of Confusion
Fogging of face mask	Small child, small area of fogging, hard to see Glare from ceiling lights on face mask that looks like fogging
Rise and fall of chest	Small child, small chest movements Child covered with warm blankets/gown Heart beating mistaken for chest rising/falling from lung expansion
Green bag on ventilator collapsing and re-expanding	If poor seal with face mask, won't see the green bag inflate/deflate
Audible breathing	Small child, noisy environment, hard to hear breath sounds peripherally
Pink vs. blue (cyanotic) child	Cyanosis mistaken for dim lighting or skin tone, but really it's a cyanotic/blue/dusky child
Breath sounds on auscultation	Very difficult to fake bilateral breath sounds in a spontaneously ventilating child

What are common signs of respiratory distress in an infant? [1–4]

- Cyanosis
- Grunting
- Retractions of chest wall: subcostal, intercostal, and/or suprasternal
- Nasal flaring
- Tachypnea
- Stridor
- Wheezing
- Eventually, desaturation and bradycardia leading to cardiac arrest.

What are common causes of apnea during induction and how do you treat them?

Table 18.4 Common causes of apnea during induction and treatment options

Cause of Apnea	Treatment
Upper airway obstruction	Adjust positioning of face mask and your hands Use airway adjuncts: Oral airway; nasal trumpets less commonly used Administer continuous positive airway pressure (CPAP) by closing the airway pressure release valve and squeezing the bag constantly to maintain the CPAP
Laryngospasm	Administer positive pressure ventilation – High pressure, large volume, rapid breaths to force open the vocal cords Deepen the volatile anesthetic Ensure 100% FiO_2 If there is intravascular access → administer propofol IV and/or succinylcholine IV If there is no intravascular access → administer succinylcholine IM
Bronchospasm	Deepen the volatile anesthetic Ensure 100% FiO_2 Intubate the patient → administer albuterol via the endotracheal tube If there is intravascular access → administer epinephrine IV (reasonable starting dose is 0.1–1 mcg/kg)

How do you manage a difficult peripheral intravenous (PIV) placement during inhalational induction?

- Ideally you would have an assistant who has experience at placing pediatric PIVs.
- Consider calling for assistive devices early on when recognizing difficult PIV placement: vein finder, ultrasound.
- Common locations for PIV placement when you cannot see a vein directly:
  - Hand

    Between third and fourth metacarpals
    Between fourth and fifth metacarpals
    "Intern vein" proximally on the lateral wrist proximally, or distally between the first and second metacarpals

- Anterior distal forearm
- Foot

  Saphenous – often placed blindly by anatomical landmarks
  Lateral foot
  Dorsum of foot

What is most dangerous about inhalational induction? [1–4]

- Many things can go wrong during inhalational induction. One of the most dreaded is laryngospasm that occurs before you've established IV access.
- What if you have an assistant who cannot place a peripheral IV and you are now the most experienced person to do it? What if simultaneously the patient laryngospasms, and now you need to deliver high positive pressure breaths to try to break the laryngospasm? What if you are unsuccessful at mechanically breaking the laryngospasm with positive pressure breaths?
  - The fastest option would be to administer succinylcholine 4 mg/kg intramuscular to provide muscle relaxation as fast as possible.
  - Then with muscle relaxation in effect, the vocal cords should relax and the laryngospasm should break.
  - Proceed with intubating the patient as fast as possible.
  - Now with a secure airway, you can work on establishing intravenous access.
  - For this reason, you may want to have a pre-drawn syringe of succinylcholine and an IM needle readily available within arm's reach every time you do an inhalational induction. When laryngospasm during mask induction occurs, it can be quite dramatic and stressful. The patient will desaturate and become bradycardic quickly. You will likely panic. The last thing you want to be doing is taking your hands and eyes off of the patient to locate a vial of succinylcholine and an IM needle and trying to draw it up while remembering the correct dose.
- What if the airway is not secured (i.e. still just bag-masking the patient), but you need to place the peripheral IV yourself? What are your options to secure the airway so that your hands are free to place a peripheral IV?
  - Mask ventilate the patient to a MAC of at least 2.0.

    Option 1: Place an LMA – it is not as secure as an endotracheal tube, but it avoids you touching the vocal cords and minimizes the risk of inadvertently causing laryngospasm before you've established IV access.
    Option 2: Intubate – provides a secure airway with an endotracheal tube, but poses risk of causing laryngospasm since you haven't given any IV induction agent and no muscle relaxant. You may consider topicalizing the vocal cords with lidocaine laryngo-tracheal aerosol prior to intubation.

What are common pediatric emergency drug doses that you should know? [1–4]

- Epinephrine
  - Code dose: 10 mcg/kg
  - Hypotension or bronchospasm: 0.1–1 mcg/kg
- Succinylcholine
  - 2 mg/kg IV
  - 4 mg/kg IM
- Atropine
  - 20 mcg/kg IV
  - 20 mcg/kg IM
  - There is no longer a minimum dose of 100 mcg.

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Chapter 19
Local Anesthetic Systemic Toxicity (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss indications for suspicion of local anesthetic systemic toxicity (LAST).
2. Review management of LAST.

Simulator Environment

1. Location: post-anesthesia care unit (PACU) of a children's hospital.
2. Manikin setup:
   (a) Age: infant.
   (b) Lines: 1 x 24 Gauge (G) peripheral intravenous (PIV) catheter
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 3-lead electrocardiogram (EKG), pulse oximeter
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, intralipid.

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4. Equipment available:
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 3-lead EKG.
   (c) Crash cart with defibrillator

Actors

1. PACU nurse
   (a) The PACU nurse is helpful and very concerned about the patient's cyanosis.
2. Anesthesiologist who did the case
   (a) The anesthesiologist who took care of the child in the operating room and who performed the caudal block is busy in the operating room taking care of another child now. They give a quick sign-out but are unable to come to help.

Case Narrative

1. Scenario background given to participants:
   (a) The patient is a healthy, ex-38-weeker, 6-month-old boy, 7 kg who just underwent a circumcision and arrived in PACU 30 minutes ago. The nurse paged the anesthesiologist on-call because the patient seems to be shivering a lot and looks a little cyanotic.
2. Scenario development
   (a) Phase 1: evaluation for shivering
      (i) The learner should go to evaluate the baby at bedside. The patient covered up in blankets and will be shivering and have perioral cyanosis. Vital signs show tachycardia heart rate (HR) 130 s, blood pressure (BP) 70s/40s, oxygen saturation (SpO_2) 80s%, high respiratory rate (RR).
      (ii) The learner should check a temperature to rule out hypothermia and should uncover the baby to perform a thorough physical exam.
      (iii) The learner should gather more information from the nurse, including administration of recent medications. On physical exam, the learner/nurse should notice that there is a Band-Aid over the patient's back and start to think of a caudal block that was not reported in sign-out.
      (iv) The learner should try to call the anesthesiologist who did the case, and they will learn that the anesthetic went fine except that they did a caudal block at the beginning of the case and it didn't seem to work well. The patient ended up receiving fentanyl 2 mcg/kg, acetaminophen 15 mg/kg IV, and the surgeon performed a penile block.

(v) While performing this history and physical exam, the learner should provide supportive care including administering supplemental oxygen (simple face mask, bag mask ventilation). For suspicion of seizure, the learner may consider administering midazolam 0.1 mg/kg.

(b) Phase 2: treatment of LAST

(i) The learner should treat with intralipid: bolus 1.5 cc/kg and infusion 0.25 cc/kg/min.

(ii) The learner may consider intubating the patient.

Scoring Rubric

Table 19.1 Scoring rubric for case scenario on Pediatric Local Anesthetic Systemic Toxicity (LAST)

Topic: Pediatric Local Anesthetic Systemic Toxicity		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Shivering		
Go to evaluate patient at bedside		
Obtain recent set of vital signs		
Check rectal temperature for highest accuracy		
Uncover baby for physical exam		
Obtain history: Recent medication administration in post-anesthesia care unit (PACU), intraoperative course and any complications		
Provide supportive care: Supplemental oxygen		
For suspected seizure, administer midazolam 0.1 mg/kg		
Identify local anesthetic systemic toxicity from intraoperative caudal block as etiology of "shivering"		
May administer meperidine 0.25 mg/kg for "shivering" while performing assessment		
Local anesthetic systemic toxicity		
Call for help		
Provide supplemental oxygen (nasal cannula, simple face mask, bag-valve mask, re-intubation)		
Identify respiratory distress due to local anesthetic systemic toxicity (LAST) and seizure		
Re-intubate in a timely fashion		
Call pharmacy for Intralipid		
Administer Intralipid 1.5 cc/kg bolus over 10–15 minutes and Intralipid 0.25 cc/kg/min as infusion		
Provide hemodynamic support (ephedrine, caution with epinephrine dosing, dopamine)		

Summary of Clinical Teaching Points

How does local anesthetic toxicity (LAST) occur? [1, 2]

- Etiology:
  - Unintended intravascular injection

    Symptoms typically present within the first 5 minutes
  - Absorption from peripheral tissue or epidural injection
- Extent of absorption depends on route and site of injection
  - Blood/intravenous > tracheal > intercostal > caudal > epidural > brachial plexus > sciatic > subcutaneous
  - BICEPS
- Risk factors
  - Extremes of age
  - Cardiac disease
  - Hepatic dysfunction
  - Hypoxemia
  - Acidosis
- Generally central nervous system toxicity will occur before cardiac toxicity

What are the central nervous system (CNS) features of LAST? [1, 2]

- Initial excitatory phase: perioral numbness and tingling, shivering, muscle tremors, tonic-clonic seizures
- Eventual depressant phase: coma, hypoventilation, respiratory arrest

What are the cardiac features of LAST? [1, 2]

- Initial excitatory phase: tachycardia, hypertension
- Direct cardiac toxicity: arrhythmias, decreased contractility, electrical conduction delay
  - Inhibition of sodium, potassium, and calcium channels
  - Prolonged PR and QRS intervals
  - Depression of SA and AV nodes
  - Prolonged QT
  - Ventricular tachycardia, ventricular fibrillation, Torsades
- Bupivacaine is the most arrhythmogenic. It binds tightly to myocyte sodium channels. Of the local anesthetics, it is most refractory or resuscitation. Severe LAST due to bupivacaine may require cardiopulmonary bypass.

What are special considerations for performing Advanced Cardiac Life Support (ACLS) in LAST? [1, 2]

- Treat seizures as soon as possible with benzodiazepines
- Prioritize oxygenation and ventilation to avoid acidosis
- Administer Intralipid early
- Use lower dose epinephrine 1 mcg/kg (versus the full code dose of 10 mcg/kg)
- Avoid vasopressin, beta blockers, calcium channel blockers, or additional local anesthetics
- Consider mobilizing resources for extra-corporeal membrane oxygenation (ECMO) / cardiopulmonary bypass if necessary

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Chapter 20
Malignant Hyperthermia (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Describe signs and symptoms of malignant hyperthermia.
2. Discuss management of malignant hyperthermia.

Simulator Environment

1. Location: operating room in an adult hospital
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 × 20 Gauge (G) peripheral intravenous (PIV) catheter
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, calcium chloride.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator
   (e) Malignant hyperthermia containing dantrolene (Ryanodex formulation)
   (f) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy opening trays, not paying attention during induction.
2. Circulator nurse
   (a) The nurse is busy helping the circulator open trays.
3. Surgeon
   (a) The surgeon is on the phone at the computer dictating their operative note from a previous patient.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist starting a case of 30-year-old male, body mass index (BMI) 58, with poorly controlled type 2 diabetes mellitus, severe gastro-esophageal reflux disease (GERD) (refluxes when lying supine), with diabetic neuropathy, scheduled for elective inguinal hernia repair.
   (b) Medications: insulin, metformin, gabapentin.
   (c) Preoperative labs: potassium 4.9, hemoglobin 11.5, bicarbonate 30.

Scenario Development

1. Phase 1: elevated end-tidal carbon dioxide ($ETCO_2$) with induction
   (a) The learner should perform a rapid sequence induction with either succinylcholine or rocuronium. The learner will place the patient on volatile anesthetic for maintenance of anesthesia.

(b) Regardless of the choice of paralytic for induction and intubation, the patient will demonstrate a high $ETCO_2$ 60's when first being placed on the ventilator. The $ETCO_2$ will increase and the learner will be unable to hyperventilate the $ETCO_2$ to lower levels. The temperature will increase. The patient will become increasingly tachycardic.
(c) The learner should take steps to diagnose malignant hyperthermia, including: hyperventilation, checking circuit, checking the absorbent, increasing flows, checking temperature probe, and checking an arterial blood gas (ABG) to evaluate for combined metabolic and respiratory acidosis.

2. Phase 2: malignant hyperthermia protocol.

(a) The learner should activate the hospital malignant hyperthermia protocol.

(i) Call for the malignant hyperthermia cart.
(ii) Administer dantrolene.
(iii) Treat hyperkalemia: insulin, glucose, albuterol, hyperventilation, calcium chloride, furosemide, sodium bicarbonate.
(iv) Place an arterial line and check serial arterial blood gases to trend resolution of metabolic and respiratory acidosis.
(v) Fluid resuscitate to prevent myoglobinuria.
(vi) Place foley catheter to monitor urine output.
(vii) Cool patient to normothermia.
(viii) Establish large-bore PIV access.

(b) The learner should prepare the patient for intensive care unit (ICU) disposition.

Scoring Rubric

Table 20.1 Scoring rubric for case scenario on Malignant Hyperthermia

Topic: Malignant Hyperthermia (Adult)			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Malignant hyperthermia			
Respiratory	Hyperventilates to treat hypercarbia initially		
	Checks ventilator circuit, endotracheal tube (ETT), sampling line, water trap, and/or absorbent canister to verify hypercarbia		

(continued)

Table 20.1 (continued)

Communication	Identifies malignant hyperthermia crisis		
	Calls for malignant hyperthermia (MH) cart		
	Calls for help / anesthesia STAT		
	Communicates MH crisis to surgeons and asks them to quickly finish or abort surgery		
Diagnosis	Identifies mixed respiratory and metabolic acidosis		
	Identifies muscle rigidity		
	Identifies rising $ETCO_2$ that cannot be hyperventilated off		
	Identifies hyperthermia		
Management	Discontinues triggering agents		
	Hyperventilates at 100% fraction of inspired oxygen (FiO_2) at high flows		
	Administers dantrolene 2.5 mg/kg		
	Replaces circuit, water trap, and absorbent		
	Enacts cooling measures (bladder irrigation, abdominal irrigation, ice packs to axilla and groin, forced air cooling)		
	Fluid resuscitates patient		
Lines	Places Foley catheter to ensure adequate urine output		
	Places arterial line		
	Established large-bore peripheral intravenous (PIV) access		
Labs	Orders arterial blood gas (ABG), +/− complete blood count (CBC), basic metabolic panel (BMP), coagulation studies, creatine phosphokinase (CPK), and urine myoglobin labs		
	Checks serial ABGs		
Hyperkalemia			
Diagnosis	Diagnoses severe hyperkalemia		
Management	Hyperventilates patient		
	Administers calcium chloride 10 mg/kg		
	Administers insulin 0.1 units/kg		
	Administers dextrose 0.5 g/kg (dextrose 50% 1 cc/kg)		
	Administers sodium bicarbonate 1 mEq/kg		
	Administers albuterol		

Summary of Clinical Teaching Points

How does malignant hyperthermia occur? [1–3]

- Pathophysiology
  - Malignant hyperthermia is a disorder of skeletal muscle metabolism that, when triggered, results in a hypermetabolic process.

  - Various genetic mutations related to the Ryanodine Receptor (RyR) can cause patients to be malignant hyperthermia (MH)-susceptible.
  - The mechanism is uncontrolled relase of calcium via RyR from the sarcoplasmic reticulum.

- Triggers
  - Volatile anesthetics (isoflurane, halothane, sevoflurane, desflurane)
  - Succinylcholine – masseter muscle spasm has a 50% association with malignant hyperthermia
  - Nitrous oxide is NOT a trigger
  - Heat, stress, exercise – patients may have a history of muscle fatigue or weakness due to these, and may later be found to be MH-susceptible (examples: children playing outdoors in the summer, young military recruits)

What are the clinical features of malignant hyperthermia? [1–3]

- Profoundly high end-tidal carbon dioxide ($ETCO_2$) that is not subtle and cannot be hyperventilated off despite increasing minute ventilation
- Hyperthermia – often a delayed finding; may increase 1 °C every 5 minutes and reach as high as 45 °C
- Hemodynamic instability – arrhythmias
- Rhabdomyolysis, myoglobinuria, resulting in renal failure
- Mixed metabolic acidosis and respiratory acidosis
- Extreme muscle rigidity (e.g. cannot even extend the patient's wrist for arterial line positioning)
- Disseminated intravascular coagulopathy
- Presents anywhere from immediately post-administration of triggering agent to 12–24 hours later

How do you diagnose malignant hyperthermia? [1–3]

- If MH-susceptibility is suspected pre-operatively → a halothane contracture test can be performed from a muscle biopsy, but this is only done at a handful of centers around the entire country.
- If MH occurrence is suspected intraoperatively
  - Send an arterial blood gas – confirmed by the presence of a mixed metabolic acidosis and respiratory acidosis
  - Presence of high $ETCO_2$ that is profound and that you cannot ventilate off despite increasing the respiratory rate and tidal volume (e.g. $ETCO_2$ in the 80s despite 20 L/min minute ventilation)

- Diseases with the clearest association with malignant hyperthermia
  - King-Denborough Syndrome
  - Central Core Disease
  - Multiminicore Disease
  - MH is NOT associated with muscular dystrophy – these are associated with rhabdomyolysis, but not necessarily malignant hyperthermia

What are differential diagnoses for malignant hyperthermia (i.e. how might you misdiagnose malignant hyperthermia for something else)? [1–3]

- Hyperthermia secondary to warm Bair hugger
- Hypercarbia from hypoventilation
- Tachycardia from pain
- Sepsis
- Thyroid storm
- Pheochromocytoma
- Drug intoxication
- Neuroleptic malignant syndrome
- Serotonin syndrome

How do you treat malignant hyperthermia? [1–3]

- Call for help – you will need a lot of extra hands.
- Call for the MH cart.
- Call the Malignant Hyperthermia Association of the United States (MHAUS) hotline for guidance on running the MH code and patient/family counseling post-operatively.
  - MHAUS hotline number is 1–209–417-3722
- Dantrolene! Dantrolene! Dantrolene!
  - If you suspect an MH crisis, call for the MH cart STAT and start assigning designated staff members to reconstitute and prepare the dantrolene. You will likely need to administer repeated boluses of dantrolene.
  - Give the dantrolene early in the resuscitation.
  - Start with dantrolene 2.5 mg/kg IV and continue repeated and uptitrated boluses based on clinical features and arterial blood gas (ABG) resolution of the metabolic and respiratory acidosis.
  - The maximum dose of dantrolene at a time is 10 mg/kg IV.
  - You may need to give repeated boluses.
- Post-operatively, the patient must go to the intensive care unit (ICU)
  - 25% of patients in an MH crisis will have recrudescence after the initial episode and have incomplete resolution.
  - In the ICU, it is reasonable to continue dantrolene boluses of 1 mg/kg IV every 6 hours or as an infusion of 0.25 mg/kg/min.
  - The patient will require close monitoring for at least the next 24–48 hours.

How difficult is it to reconstitute dantrolene? [1–3]

- Old formulation of dantrolene
  - 1 vial contains dantrolene 20 mg and mannitol 3 grams. Reconstitute with 60 mL of sterile water until the solution is a clear-orange color. It is a 22-minute reconstitution for a single vial.

  - Example: for a 70 kg patient receiving a 2.5 mg/kg starting dose of dantrolene, you would need 175 mg, which requires reconstituting 9 vials for one dose. That is a lot of manual labor.

- New formulation of dantrolene
  - 1 vial contains dantrolene 250 mg and mannitol 150 mg. Reconstitute with 5 mL of sterile water. It is a 1-minute reconstitution time for a single dose.
  - That is a lot less manual labor.

- The dosing of dantrolene is the same, regardless of formulation: initial bolus of 2.5 mg/kg and repeat until MH symptoms and labs improve. This may require dosing over 20 mg/kg.
- Side effect of dantrolene: muscle weakness.

How do you treat malignant hyperthermia? [1–3]

- Dantrolene – give it early
- Initiate Advanced Cardiac Life Support (ACLS) and other supportive measures
- Intubate if patient does not already have an endotracheal tube. Provide adequate oxygenation and hyperventilation.
- Establish large bore peripheral intravenous and central line access.
- Place an arterial line for frequent serial arterial blood gases.
- Fluid resuscitate with IV fluids to prevent renal failure. Maintain adequate urine output with a goal of >1 cc/kg/hr.
- For treatment of hyperthermia: place cooling packs to the axillae and groin; infuse cold intravenous fluids; consider bladder irrigation or peritoneal irrigation with cold fluids; monitor the core temperature carefully; can stop cooling measures once the temperature is below 38 °C.
- Stop inciting agents. Switch out the ventilator if possible. If not, then switch out the circuit and absorbent. Place charcoal filters. May consider using a Mapleson circuit, but this requires an extra person just to hyperventilate.
- Switch to a total intravenous anesthetic (TIVA).
- Do not give calcium channel blockers – these are contraindicated in an MH crisis. Calcium channel blockers can lead to hemodynamic instability and cardiac arrest in the setting of dantrolene administration. Dantrolene is specifically a calcium channel blocker unique to the ryanodine receptor.

What are the cardiac signs of hyperkalemia? [1–3]

Table 20.2 Cardiac signs of hyperkalemia based on serum potassium level

Serum Potassium Level	Possible Cardiac Changes
Mild (5.5–6.5 mEq/L)	Peaked T waves Prolonged PR segment
Moderate (6.5–8.0 mEq/L)	Loss of P wave Prolonged QRS complex ST-segment elevation Ectpoic beats and escape rhythms

(continued)

Table 20.2 (continued)

Serum Potassium Level	Possible Cardiac Changes
Severe (>8.0 mEq/L)	Progressive widening of QRS complex Sine wave Ventricular fibrillation Asystole Axis deviations Bundle branch blocks Fascicular blocks

What is the treatment of hyperkalemia in pediatric and adult patients?

Table 20.3 Pharmacologic management of hyperkalemia in adult versus pediatric patients

Adult Patient	Pediatric Patient (think Adult dose divided by 100 kg)
Hyperventilate	Hyperventilate
Insulin 10 units IV	Insulin 0.1 units/kg IV
D50% 1 ampule = 50 cc of dextrose 500 mg/mL = 25 grams of dextrose	D50% 0.5 mg/kg = 1 cc/kg D25% 0.5 mg/kg = 2 cc/kg
Calcium chloride 1 gram = 1000 mg	Calcium chloride 10 mg/kg (administer slowly and cautiously, consider central venous access.)
Sodium bicarbonate 1 ampule = 50 mEq / 50 mL	Sodium bicarbonate 1 mEq/kg = 1 cc/kg
Albuterol puffs	Albuterol puffs
Furosemide 20 mg	Furosemide 0.5 mg/kg (max 10 mg)

How do you counsel patients and family members postoperatively? [1–3]

- There are a variety of possible genetic mutations that can make a patient malignant hyperthermia (MH)-susceptible.
- If it is an autosomal dominant mutation, the child of a parent who is MH-susceptible has a 50% chance of being MH-susceptible as well.
- First-degree family members should be advised that they may also be MH-susceptible and should therefore avoid triggering anesthetics (succinylcholine and volatile anesthetics).

How do you care for a malignant hyperthermia (MH)-susceptible patient? [1–3]

- Total intravenous anesthetic (TIVA)
- No succinylcholine
- No volatile anesthetics (including sevoflurane, desflurane, and isoflurane):
  - Remove the volatile anesthetic canisters from the ventilator.
  - Change the absorbent.
  - Consider changing the inspiratory and expiratory valves and the oxygen sensors.

  - Flush the ventilator at 10–15 L/min with 100% fraction of inspired oxygen (FiO_2) for at least 10–20 minutes.
  - Place charcoal filters.

- Know where your hospital's malignant hyperthermia cart is located and consider bringing it closer to your operating room for ease of access.

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Chapter 21
Post-Fontan, Single Ventricle (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Describe single ventricle physiology.
2. Discuss anesthetic goals for managing single ventricle physiology.

Simulator Environment

1. Location: operating room in an adult hospital
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 × 20 Gauge (G) peripheral intravenous (PIV) catheter
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter.
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, dopamine, albuterol, fentanyl, midazolam.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator
   (e) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy opening trays.
2. Circulator nurse
   (a) The nurse has only every taken care of adults and has no experience with pediatric or cardiac surgeries. The nurse is helpful but the anesthesiologist needs to be very clear and direct with instructions.
3. Surgeon
   (a) The surgeon is on the phone at the computer dictating their operative note from a previous patient.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist starting a case of 25-year-old female, gravid 1 para 0 at 16 weeks estimated gestational age, with hypoplastic left heart syndrome, post-Norwood, post-Glenn, and post-Fontan, who is here for dilation and evacuation.
   (b) Preoperative history: ex-28-weeker twin; diagnosed prenatally with hypoplastic left heart syndrome. Status post Norwood-Blalock-Taussig shunt at 3 days of life; status post Glenn and Blalock-Taussig shunt takedown at 5 months of age; status post fenestrated Fontan at 3 years of age.
   (c) Cardiac History (this information will only be provided if the learner specifically asks for it): She previously received all her cardiology care and surgeries at the local children's hospital, but since turning 21 years old, she has been transitioning to adult clinics. She last saw her Cardiologist 2 months ago and he recommended that she not proceed with the pregnancy due to her high risk. She is moderately active; mostly works at a desk office job, but does yoga and light walking 3–5 times a week.

(d) Obstetric History: She receives regular prenatal care at High-Risk Obstetrics Clinic. Her fetus was found to have a non-survivable neurologic and cardiac morphology. After much deliberation, she decided to terminate the pregnancy. She has had little appetite and been vomiting daily throughout her pregnancy due to morning sickness. Last ate >12 hours ago.
(e) Medications: furosemide 20 mg per oral twice daily (no recent changes in her dosing); prenatal vitamins.
(f) Preoperative trans-thoracic echocardiogram (TTE) (this information will only be provided if the learner specifically asks for it): mildly decreased systolic shortening of the right ventricle; mildly impaired diastolic filling of right ventricle; patent shunts from superior vena cava (SVC) to the pulmonary artery (PA) and inferior vena cava (IVC) to the pulmonary artery (PA). A fenestration between the IVC and right atrium (RA) is noted with some flow from the IVC to the PA. Moderate ventricular septal defect (VSD) and moderate atrial septal defect (ASD) are present. There is good flow through the aorta with no stenosis or narrowing.
(g) Preoperative physical: dusky appearing but patient says she always looks like this; well-nourished, well-groomed, gravid uterus. Breath sounds clear to auscultation bilaterally. Minimal crackles in lung bases bilaterally.
(h) Preoperative vital signs: oxygen saturation (SpO_2) 85% on room air, heart rate (HR) 85 beats per minute (bpm); blood pressure (BP) 110/80; temperature 36.5 °C.
(i) Preoperative labs: hemoglobin 16, platelet 250, potassium 4.5, bicarbonate 24, INR 1.1.

Scenario Development

1. Phase 1: pre-operative planning and choice of anesthetic
   (a) The learner should take the time to do a briefing with the OR team about the patient's single ventricle physiology, and review why this is a higher risk case, what their anesthetic goals are, and how the staff can assist them.
   (b) The learner should consider administering a fluid bolus (e.g. crystalloid 20 cc/kg) prior to induction.
   (c) The learner may consider monitored anesthesia care (MAC)/sedation with neuraxial technique versus general anesthesia with laryngeal mask airway (LMA) or endotracheal tube (ETT). Most likely, the learner will choose to do a general anesthetic.
2. Phase 2: hypotension during induction
   (a) The learner may choose induction medications that avoid decreases in preload and afterload (e.g. any combination of etomidate, propofol, and narcotic).

(b) Regardless of the learner's initial steps, the patient will become hypotensive and subsequently desaturate after induction.
(c) The learner should intervene by trying to decrease pulmonary vascular resistance (PVR) (avoid hypoxemia, hypercarbia, and acidosis), augment preload (administer fluid bolus), and may consider supporting contractility with an inotropic agent (e.g. dopamine, epinephrine, norepinephrine, dobutamine). The vital signs will improve with these interventions.
(d) If the learner does not appropriately intervene, then the patient will go into cardiac arrest, manifested in the form of arrhythmias (e.g. asystole) requiring initiation of advanced cardiac life support (ACLS).

Scoring Rubric

Table 21.1 Scoring rubric for case scenario on Young Adult Post-Fontan

Topic: Young Adult Post-Fontan (Pediatric)		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Pre-operative evaluation		
Obtains set of baseline vital signs. Identifies low oxygen saturation (SpO_2). Confirms with patient if this is baseline		
Obtains thorough history about symptoms: Syncope, cyanosis, fatigue, chest pain, dyspnea at rest or on exertion		
Obtains history about cardiac workup: Recent visit to cardiologist, medications (compliance, up/down-titration of dosing), recent echocardiogram, surgical repairs, right or left heart catheterization		
Identifies key information from echocardiogram: Systolic function, diastolic function, patency of shunts, presence of fenestration, presence of collaterals, flow through aorta and flow through pulmonic circulation		
Obtains obstetric past medical history (PMH), complications, prenatal care		
Performs physical exam and identifies cyanosis, crackles in lung bases. Confirms with patient if this is baseline		
Induction		
Prepares cardiac medications: Inotropes and/or vasopressors		
Places awake arterial line		
Fluid resuscitates the patient prior to induction (e.g. crystalloid 20 cc/kg)		
May perform huddle with operating room (OR) team to discuss possible complications and backup plans		
Weighs pros and cons of monitored anesthesia care (MAC)/sedation with neuraxial block versus general anesthetic with laryngeal mask airway (LMA) versus endotracheal tube (ETT)		

Table 21.1 (continued)

Avoids increases in pulmonary vascular resistance: Avoid hypoxemia, hypercarbia, and acidosis		
Maintains normal or slightly elevated P_aCO_2 to improve venous return		
Augments contractility with inotropic agent (e.g. dopamine, epinephrine, norepinephrine)		
Augments mean arterial pressure with vasopressors (e.g. phenylephrine)		
Treats arrhythmias appropriately with advanced cardiac life support (ACLS) and cardioversion		

Summary of Clinical Teaching Points

What is single ventricle physiology? [1, 2]

- One ventricle pumps all the pulmonary venous blood into the systemic circulation.
- One atrium receives all the systemic venous return from the body.
- Origins are infinite – many possible variations of cyanotic congenital heart disease.
- Surgical staged repairs are pretty similar in concept: Norwood → Glenn (also known as Hemi-Fontan) → Fontan.

Why do I need to learn single ventricle physiology if I am not specializing in pediatric anesthesiology? [1, 2]

- Children are living longer into adulthood and coming to adult hospitals, and therefore operating rooms, for adult medical issues.
- Even if you do not do pediatric anesthesia, you will likely care for a post-Fontan adult-aged patient at some point in your career.

What is the most common congenital heart disease that would result in single ventricle physiology? [1, 2]

- Hypoplastic left heart syndrome is the most common.
- "No flow, no grow." – if there is no blood flow in utero to that part of the heart (chamber, vessel), it will not grow.
- It's all about balancing Q_p and Q_s.
  - Q_p = pulmonary blood flow
  - Q_s = systemic blood flow
  - SVR = systemic vascular resistance
  - PVR = pulmonary vascular resistance
  - MAP = mean arterial pressure
  - SpO_2 = oxygen saturation

  - If there is high SVR and low PVR, the cardiac output will be a small amount of oxygenated blood (low MAP and high SpO_2).
  - If there is low SVR and high PVR, the cardiac output will be a large amount of deoxygenated blood (high MAP and low SpO_2).

- A small, underdeveloped left atrium and left ventricle results in a small, underdeveloped aorta. This leads to a small amount of oxygenated blood being delivered systemically and results in death at birth.
- Survival is dependent on a patent ductus arteriosus: de-oxygenated blood can be shunted from the pulmonary artery to the aorta, resulting in a moderate amount of mixed-oxygenated blood being delivered systemically and producing an alive baby at birth with an SpO2 in the 70–80s%.
- Newborns with this suspected cyanotic congenital heart disease are quickly placed on prostaglandin (PGE) infusion at birth to keep the patent ductus arteriosus shunt open until they can be repaired surgically.

What happens in a Norwood surgery? [1, 2]

- Norwood surgical repair typically occurs within the first few days of life.
- Up until this point, the newborn is surviving because of the patent ductus arteriosus shunt, which is being kept open by an intravenous infusion of prostaglandin medication.
- Surgical steps of the Norwood repair:
  - Takedown of the patent ductus arteriosus.
  - Creation of a neo-aorta: connect the proximal pulmonary artery to the aorta. This converts the right ventricle to a single ventricle that pumps blood into the systemic circulation.
  - Creation of a shunt as a new source of pulmonary blood flow.

    Blalock-Taussig shunt: blood flows from the aorta to the pulmonary artery.
    Sano shunt: blood flows from the right ventricle to the pulmonary artery.

What happens in a Glenn (also known as Hemi-Fontan) surgery? [1, 2]

- Glenn surgical repair typically occurs by 6 months of age.
- Surgical steps of the Glenn repair:
  - Takedown of the shunt to the pulmonary artery (most commonly either the Blalock-Taussig shunt or the Sano shunt).
  - Connection of the superior vena cava (SVC) to the pulmonary artery (PA).
- What are the new anesthetic challenges in a post-Glenn heart?
  - The heart now relies on passive venous return of blood from the superior vena cava to the pulmonary circulation.
  - Need to avoid high pulmonary vascular resistance to ensure adequate pulmonary blood flow.

  - Counterintuitively, the patient will benefit from a high end-tidal carbon dioxide ($ETCO_2$) level. Higher $ETCO_2$ results in cerebral vessel dilation and maximizes passive cerebral venous drainage to the SVC to the PA.
  - Need to maintain adequate pre-load. Avoid hypovolemia.

What happens in a Fontan surgery? [1, 2]

- Fontan surgical repair typically occurs around 1.5 to 3 years of age.
- Surgical steps of the Glenn repair:
  - Connection of the inferior vena cava (IVC) to the pulmonary artery (PA).
- What does this mean?
  - Now nearly all systemic venous return will passively drain into the pulmonary artery.
  - Only the thebesian, coronary sinus, and bronchial veins will drain into the right atrium.
- Why might a patient have a fenestrated Fontan?
  - The fenestration serves as a back-up option that can be thought of as a pop-off valve.
  - There may be cases where patients have high pulmonary vascular resistance (e.g. stenosis, clot, intrinsic pulmonary hypertension).
  - The goal is to avoid blood flow backing up into the superior vena cava (and causing superior vena cava syndrome) or into the inferior vena cava (and causing peripheral edema, hepatic venous congestion).
  - The fenestrated Fontan serves as a back-up option in cases of high pulmonary vascular resistance where not enough venous blood can flow passively from the SVC and IVC directly to the pulmonary artery.
  - Instead, de-oxygenated venous blood will drain from the inferior vena cava through the fenestration and into the right atrium. This de-oxygenated blood will then flow directly to the right ventricle and out the aorta.
  - If a patient has a fenestrated Fontan and blood does flow through it, then this will result in mixed-oxygenated blood going into systemic circulation, resulting in an oxygen saturation (SpO_2) that is less than 100% and which is considered normal for this patient.

What are possible complications in a post-Fontan patient? [1, 2]

- If the single ventricle is the right ventricle…
  - The right ventricle has different morphology and different composition from the left ventricle.
  - The right ventricle was never designed to have to contract and pump against high pressures of the systemic circulation.
  - Over time, the single ventricle will hypertrophy and gradually be unable to contract and fill well.

  - Warning signs of a failing single ventricle: poor diastolic filling, poor systolic shortening (a.k.a. not contracting well).

- Over time, patients can develop obstructions to the passive venous drainage into the pulmonary arterial circulation.
  - Patients with high pulmonary vascular resistance may require phosphodiesterase inhibitors.
  - Patients with pulmonary artery stenosis may require balloon dilations and stent placements.
  - Clots can develop at any juncture or within the vasculature, proximally or distally.
- There can be too much pulmonary blood flow.
  - Pulmonary circulation overload results in pulmonary edema. Treatment may include diuresis and banding of the pulmonary artery.
  - Pulmonary vascular remodeling can lead to high pulmonary vascular resistance.
- These kids will undergo many trips to the operating room and cardiac catheterization lab.

What do you need to know pre-operatively? [1, 2]

- Recent echocardiogram (ideally done within the past 1 year or sooner if there have been changes in symptoms).
  - Contractility: how well is the single ventricle contracting (the report often contains qualitative descriptions of systolic shortening)?
  - Filling: how well is the single ventricle filling during diastole?
  - Patency of shunts
  - Presence of reversal of blood flows
- Medications – has the patient required uptitration of their cardiac medications recently?
  - Diuretics
  - Phosphodiesterase inhibitors
  - Remodeling agents
- Functional status
- Fluid and volume status
- Labs: complete blood count (CBC), may desire hemoglobin (Hb) > 10 to maximize oxygen-carrying capacity in a patient with significant cardiac disease.

What do you need to prepare your room set-up? [1, 2]

- Fluids
  - Crystalloid of choice (lactated ringers, plasmalyte, normal saline) – can administer a starting bolus of 20 cc/kg.

  - Colloid (e.g. 5% albumin) – can administer a starting bolus of 10–15 cc/kg.
- Inotropes to support contractility
  - Examples: dopamine, epinephrine, norepinephrine, dobutamine.
- Packed red blood cells (PRBCs)
  - Consider transfusing to goal hemoglobin >10 to maximize oxygen-carrying capacity.
- If it's a tertiary care center and patient is undergoing major surgery, consider having inhaled nitric oxide available to decrease pulmonary vascular resistance.

What are your anesthetic goals? [1, 2]

- Avoid high pulmonary vascular resistance by avoiding hypoxemia, hypercarbia, acidosis, pain, and hyperthermia.
- Counterintuitively, you may aim for a high end-tidal carbon dioxide ($ETCO_2$) and high P_aCO_2 to provide cerebral vasodilation. This helps promote passive venous drainage from the cerebral circulation.
- Maintain preload, avoid hypovolemia.
  - Absolute hypovolemia: intravascularly depleted, exacerbated by nil per os (NPO) status and sensible and insensible losses intraoperatively.
  - Relative hypovolemia: examples include ventilation with high peak pressures or high positive end-expiratory pressure (PEEP), intra-abdominal or intrathoracic insufflation, reverse Trendelenburg positioning.
- Augment contractility with inotropes as needed.

Where should the patient go post-operatively? [1, 2]

- The patient with single-ventricle physiology is preload-dependent.
  - If this patient becomes hypovolemic, they will have poor venous return into the pulmonary circulation. This results in hypoxemia, hypotension, and poor cardiac output, and will eventually put this patient into heart failure.
- This type of patient cannot go home unless they can adequately tolerate per oral (PO) intake.
  - Minimize post-operative nausea and vomiting with anti-emetics and adequate fluid resuscitation perioperatively.
  - Encourage PO fluid intake postoperatively as tolerated.
  - If patient has poor PO intake due to severe PONV, admit to the hospital overnight for IV fluid administration until PO intake improves.

Why is it important to avoid the rush to induce? [1, 2]

- Assume your staff knows nothing.
  - It is your responsibility as the anesthesiologist to advocate for your patient.

  - You set the tone telling everyone that this is not a routine case.
  - Staff needs to pay attention.
  - Staff needs to know how they can help you.

- Consider doing an anesthesia-specific brief before induction.
  - Discuss the high risk of adverse events due to the presence of congenital cardiac disease.
  - Ask for a calm, quiet environment: no phone calls, no opening equipment loudly, no music.
  - Place all monitors on the patient before induction.
  - Know where emergency medications are located and have them pre-drawn.
  - Discuss with staff what could go wrong and how they can help.

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Chapter 22
Pyloric Stenosis (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Understand why pyloric stenosis is a medical and not a surgical emergency.
2. Identify and treat bradycardia due to vasovagal response.
3. Understand how to perform a rapid sequence induction in a newborn.
4. Appropriately manage aspiration that occurs during induction.
5. Recognize accidental intraoperative extubation.

Simulator Environment

1. Location: operating room of a children's hospital
2. Manikin setup:
   (a) Age: infant/newborn
   (b) Lines: 1 x 24 Gauge (G) peripheral intravenous (PIV) line that is functional
   (c) Monitors: none on patient at start of case
3. Medications available: normal saline, propofol, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, atropine.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction with Yankauer, soft suction catheter.
   (b) Monitors: pulse oximeter, blood pressure cuff, 3-lead electrocardiogram (EKG), capnogram, temperature
   (c) Lines: 1 x 24 G PIV, 250 cc bag of normal saline (NS) on a Buretrol tubing.
   (d) Crash cart with defibrillator
   (e) Paperwork: pre-operative anesthesia and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy opening trays and making lots of noises in the background during induction.
2. Circulator nurse
   (a) The nurse is helpful and attentive.
3. Surgeon
   (a) The surgery attending is asking lots of questions of the surgery fellow in the background about the size of the pyloric stenosis and whether this should be done open or laparoscopic. They are waiting for you to tell them when they can prep and drape. During the case, the surgery fellow keeps leaning their elbow on the drapes over the patient's face.
4. Medical student on anesthesia rotation
   (a) The medical student has never taken care of a newborn before and is very worried about the baby having pain, so they offer to dilute some fentanyl for you to give.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist starting a case of a 5-week-old, 5 kg baby boy here for pyloromyotomy for pyloric stenosis.
   (b) Preoperative history: ex-full term; older sibling and father both had pyloric stenosis; no recent upper respiratory infection (URI) symptoms; nil per os

(NPO) since admission 24 hours ago; hasn't eaten since admission; projectile vomiting of curdled milk last 3 days.

(c) Preoperative physical: vigorous baby boy, crying in his mother's arms

(d) Preoperative vital signs: heart rate (HR) 100, blood pressure (BP) 80/55, oxygen saturation (SpO_2) 99% on room air, temperature 37 °C

(e) Preoperative labs: sodium (Na) 135, chloride (Cl) 109, potassium (K) 4.5, bicarbonate (HCO_3) 26, creatinine (Cr) 0.8, glucose 90, hemoglobin (Hb) 12, platelets 300 K

2. Scenario development

(a) Phase 1: orogastric suctioning resulting in bradycardia

(i) The learner should perform orogastric suctioning using a soft suction catheter. This may be done in the classical "4-quadrant" method or some variation – supine, right lateral, left lateral.

(ii) The learner may or may not have pre-treated with atropine 20 mcg/kg. If the learner did not pre-treat with atropine, then bradycardia will occur in the scenario, with heart rate abruptly dropping from 120 to 60 beats per minute (bpm).

(iii) The learner should recognize the bradycardia and stop suctioning. In the scenario, the bradycardia continues to 40 bpm and the learner should give atropine 20 mcg/kg or epinephrine 1 mcg/kg, which would rapidly correct the bradycardia.

(b) Phase 2: aspiration during induction

(i) The baby will vomit during direct laryngoscopy:

1. …regardless of whether the learner performed orogastric suctioning pre-induction.
2. …regardless of choice of induction agents (etomidate, propofol, ketamine, succinylcholine, rocuronium).

(ii) To manage aspiration during induction, the learner should turn the baby on the side in right or left lateral decubitus and suction.

(iii) The learner should suction the oropharynx as quickly and thoroughly as possible with a Yankauer.

(iv) The learner should move to intubate as fast as possible.

(v) The learner may mask ventilate prior to intubation due to concern for oxygen desaturation during the aspiration event.

(vi) After intubation, the learner should pass a soft suction catheter down the endotracheal tube to remove potential aspirate.

(vii) The learner may consider performing a fiberoptic bronchoscopy to survey the tracheo-bronchial tree for evidence of aspiration.

(c) Phase 3: accidental extubation intraoperatively

(i) After the learner is ready for the surgeons to prep and drape, the baby is moved down to the middle of the table and rotated at a 90-degree angle for optimal surgical positioning.
(ii) During the case, the surgery fellow keeps leaning their hand on the patient's face.
(iii) Suddenly there is loss of capnogram and the ventilator alarms that there is a leak. The surgeon reports that they smell sevoflurane. The learner should check under the drapes and realize that the patient has been extubated.
(iv) The learner must tell the surgeons to stop the case.
(v) The learner must decide how to re-intubate – whether to stop the whole case and remove the instruments so they can bring the patient's head back to the head of the table, or whether they can re-intubate 90 degrees.
(vi) The surgeons are upset that they must interrupt the case and complain that the learner didn't secure the endotracheal tube appropriately.

(d) Phase 4: pain control

(i) The case continues and the surgeons are now able to perform the pyloromyotomy successfully.
(ii) The medical student asks if they can now give the fentanyl. The learner should recognize that opiates should not be used during pyloromyotomy due to the concern for apnea.

Scoring Rubric

Table 22.1 Scoring rubric for case scenario on Pyloric Stenosis

Topic: Newborn Pyloric Stenosis		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not Completed
Bradycardia		
Performs orogastric suctioning through repeated, gentle passage of a soft suction catheter		
May pre-treat with atropine 20 mcg/kg intravenously (IV)		
Identifies bradycardia		
Stops suctioning		
Treats bradycardia with atropine 20 mcg/kg IV or epinephrine 1 mcg/kg IV		
Administers supplemental oxygen: 100% fraction of inspired oxygen (FiO_2) via face mask		

Table 22.1 (continued)

Aspiration at induction		
Recognizes the baby is vomiting		
Turns the baby right or left lateral decubitus		
Suctions the oropharynx with a Yankauer		
Intubates in a timely fashion		
After intubation, suctions the endotracheal tube (ETT) with a soft suction catheter		
May perform fiberoptic bronchoscopy to survey the tracheo-bronchial tree for aspirate and perform deep suction and lavage		
Accidental Extubation		
Recognizes that patient was extubated		
Tells the surgeons to stop the case		
Calls for help		
Coordinates with surgeon safest positioning to reintubate the baby		
May have surgeons remove instruments and rotate patient with head back to anesthesiologist		
May re-intubate with baby remaining at 90 degrees		
Mask ventilates the baby with 100% FiO_2 to resume oxygenation and ventilation		
Re-intubates the baby in a timely fashion		
Pain control		
Decides not to administer narcotics		
Recognizes that narcotics with increase already elevated risk of postoperative apnea		
Confirms that surgeon will administer local anesthetic		
Recognizes that local anesthetic is enough for analgesia		
May administer acetaminophen 15 mg/kg IV or 20–40 mg/kg per rectum (PR)		

Summary of Clinical Teaching Points

What is pyloric stenosis? [1, 2]

- Hypertrophy of pyloric muscles.
- Appears between 3–12 weeks of age (most commonly 4–6 weeks).
- Presentation: projectile vomiting after feedings, dehydration, and failure to thrive.
- Diagnosis: history and physical exam, barium swallow study and/or ultrasound to confirm presence of pyloric stenosis and measure thickness of the pylorus muscle.
  - Diagnosis typically made by the history and clinical presentation.
  - Signs of dehydration: few wet diapers, no tears when crying; if severe, can present with poor skin turgor, sunken fontanelles, delayed capillary refill.

- Labs: ongoing loss of potassium (K+), hydrogen (H+), and chloride (Cl-).
  - Within several days: classic hypokalemia, hypochloremia, hyponatremia, and alkalosis.
  - Within several weeks: mixed metabolic acidosis and alkalosis.

Why is pyloric stenosis a medical not a surgical emergency? [1, 2]

- It is mandatory to correct electrolyte abnormalities prior to going to the operating room for surgical repair of the pyloric stenosis.
  - Goal serum chloride >100, urine chloride >20, serum bicarbonate <28, potassium >4, and normal pH.
- It is essential to adequately fluid resuscitate the baby pre-operatively.
  - These babies will be made NPO and have an OG/NG tube placed upon admission to the hospital.
  - Fluid resuscitation is done via IV fluids:

    No potassium (ex: there is potassium in Lactated Ringers and Plasmalyte) until you confirm the baby can urinate.
    Start with Normal Saline.
    Run a dextrose-containing solution at a maintenance rate (4:2:1 rule, with 4 cc/kg/h. for the first 10 kg) to avoid hypoglycemia in a newborn.
- There is an increased risk of apnea and prolonged intubation post-operatively if the patient is taken to the operating room before correcting the serum alkalosis.
  - Serum alkalosis will equilibrate with the brain and result in alkalosis of the cerebral spinal fluid (CSF). This pH alteration in the brian results in hypoventilation in an attempt to lower the pH to a normal level.

How and why do you decompress the stomach prior to induction and intubation? [1, 2]

- Goal: decompress the stomach prior to induction and intubation in order to minimize the risk of aspiration.
  - The newborn's stomach can contain as much as 100 cc of contents.
  - Due to the pyloric stenosis, the stomach contents are under high pressure and can easily exit from the stomach, up the esophagus, and into the oropharynx, where it can then move down the trachea to the lungs (i.e. aspiration).
  - This is why patients with pyloric stenosis have projectile vomiting after feeding attempts.
- Technique: perform orogastric suctioning in various positions, including supine, right lateral decubitus, left lateral decubitus, lifting up the legs, and/or sitting upright and patting on the back.
- Place all monitors on the patient prior to performing the decompression.

- Risks:
  - The baby will become very angry with orogastric suctioning.
  - The baby may have a vaso-vagal response and become bradycardic. For this reason, some providers choose to pre-treat with atropine 20 mcg/kg.
  - It may be challenging to pre-oxygenate in this setting.
  - If done traumatically, the provider may cause mucosal injury and bleeding. The provider may actually stimulate the gag reflex and induce vomiting.

What is a true rapid sequence induction and how is this done in a newborn presenting with pyloric stenosis? [1, 2]

- A newborn with pyloric stenosis has a high-pressure stomach and is at high aspiration risk.
- It is challenging to pre-oxygenate after orogastric suctioning.
- Cricoid pressure is not helpful in a baby this small.
  - It distorts the view, making intubation challenging.
  - It may stimulate vomiting if the patient is not well-anesthetized.
- There is very little time to intubate. Newborns will desaturate within less than 60 seconds.
- Avoid mask ventilation. Some providers administer small breaths after induction to prevent desaturation. This is controversial.
- Muscle relaxant options:
  - Rocuronium 1.2 mg/kg IV
  - Succinylcholine 2 mg/kg IV
- Hypnotics and analgesics
  - No opiates!
  - Propofol 2–3 mg/kg
  - Etomidate 0.2 mg/kg
  - Ketamine 1 mg/kg

What do you do if the baby vomits during induction/intubation? [1, 2]

- Turn the baby on their side – right or left lateral decubitus position – to prevent emesis from going down the trachea.
- Suction the oropharynx well.
- Intubate as fast as possible.
- After intubation, suction the endotracheal tube well. Provide positive end-expiratory pressure (PEEP).

How do you manage pain? [1, 2]

- No opiates!
  - Avoidance of opiates enables more rapid re-feeding and discharge to home.

  - These patients are at high risk of post-operative apnea, even with pre-operative correction of electrolyte derangements. Most patients are less than 60 weeks post-conceptual age.
  - Respiratory monitoring should be done for 12–24 hours post-operatively.
- Options
  - Acetaminophen 15 mg/kg IV or 20–40 mg/kg PR
  - Avoid ketorolac since under 6 months of age
  - Ketamine 0.5–1 mg/kg, can be used as an induction agent
  - Surgeon: infiltration of surgical incisions with local anesthetic is sufficient. Even if it's done "open" instead of "laparoscopic," the incisions in this size of a patient are still very small.

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Chapter 23
Status Epilepticus (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss signs and symptoms of status epilepticus.
2. Review advanced cardiac life support (ACLS) for a pregnant patient.
3. Review out-of-operating-room intubations.

Simulator Environment

1. Location: hospital lobby
2. Manikin setup:
   (a) Age: pregnant woman
   (b) Lines: none
   (c) Monitors: none
3. Medications available: code bag – propofol, etomidate, succinylcholine, rocuronium, epinephrine, phenylephrine, ephedrine.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead electrocardiogram (EKG).
   (c) Lines: arterial line kit, central line kit, peripheral intravenous (PIV) line kits
   (d) Crash cart with defibrillator

Actors

1. Code nurse
2. Medical intensive care unit (MICU) attending
3. Respiratory therapist
4. Pharmacist

Scenario Development

1. Background: You are the anesthesiologist on call and called to a code blue in the hospital lobby. Upon arrival, you find several members of the code team crowded around a patient on the floor. The patient is a young woman who appears to be term pregnant, and she is lying on the floor unconscious. A witness reports that the woman appeared to fall and start shaking her full body for a couple minutes before someone called for help.
2. Phase 1: assessment, placement of monitors, and airway management.
   (a) The learner should place monitors.
   (b) The learner should assess the patient:
      (i) Airway – determine whether the patient is spontaneously ventilating or if they require assisted ventilation or positive pressure ventilation.
      (ii) Breathing – auscultate for breath sounds.
      (iii) Circulation – check pulses, check blood pressure. Establish intravenous (IV) access and check labs, especially a fingerstick glucose. To facilitate circulation, an assistant should provide left uterine displacement or a bump should be placed under the right side.
      (iv) Disability/Exposure – check patient for injuries, trauma, especially given fall. Assume unstable cervical spine and place cervical collar. Consider possibility that patient is still seizing. Call Obstetric (OB) and neonatal intensive care unit (NICU) team for evaluation of the fetus and possible emergent delivery.
   (c) Upon assessment, the learner will find that the patient is breathing shallowly with clear but diminished bilateral breath sounds, and is still having whole

body shaking. Vital signs: heart rate (HR) 53 sinus bradycardia, blood pressure (BP) 90/50, oxygen saturation (SpO_2) 90% on non-rebreather at 10 L/min, temperature 37 °C. The patient is nonresponsive to verbal commands and sternal chest rub. She is frothing at the mouth and appears to have bitten her tongue with some bleeding. Her eyes are open and she appears to be staring straight ahead. The fingerstick glucose is 25.

3. Phase 2: treatment of hypoglycemia; intubation for airway protection; treatment of presumed status epilepticus.
   (a) The learner will determine that the patient needs to be intubated as soon as possible (ASAP) for airway protection in the setting of presumed status epilepticus.
   (b) The patient is still lying on the ground, and the learner should ask for a gurney to be brought to transport the patient.
   (c) Given that it will take some time for the gurney to arrive, the learner should move to intubate the patient on the group ASAP.
   (d) While preparing to intubate, the learner should also treat severe hypoglycemia with 1 ampule of dextrose 50%. The learner should also presume that the patient is in status epilepticus and treat with benzodiazepines. The learner should also call Neurology STAT for treatment of status epilepticus.
   (e) The learner should position themselves to optimize intubation on the floor in a potentially difficult airway.
4. Phase 3: treatment of status epilepticus
   (a) The patient is now intubated and placed on a gurney. The obstetricians has arrived and is doing fetal dopplers at bedside, which show a low heart rate. They would like the patient to be transported to the labor and delivery operating room immediately for better fetal monitoring. The obstetricians are concerned the patient may require an emergent cesarean section.
   (b) The Neurology team has also arrived. They are concerned that the patient may have sustained a head bleed from the fall and would like to do a computed tomography (CT) scan of the head, but need to ensure the patient has stopped seizing. They would like to place the patient on continuous electroencephalogram (EEG) or SEDLINE immediately.
   (c) The learner should assist with controlling seizures and improving maternal-fetal circulation by doing the following:
      (i) Ensuring adequate oxygenation – ventilating with 100% fraction of inspired oxygen (FiO_2).
      (ii) Avoiding hyperventilation, which may decrease the seizure threshold and worsen uterine perfusion pressures.
      (iii) Maintain adequate mean arterial pressure to optimize uterine perfusion.
      (iv) Control the seizures – this may be in the form of benzodiazepines and/or propofol, based on discussion with the neurologist.

Scoring Rubric

Table 23.1 Scoring rubric for case scenario on Status Epilepticus

Topic: Status Epilepticus			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not Completed
Seizure			
Primary survey	Determines whether patient is spontaneously ventilating or whether they require assisted ventilation or positive pressure ventilation		
	Auscultates for breath sounds		
	Checks pulses, places monitors and checks blood pressure		
	Provides left uterine displacement manually or via bump under right side		
	Establishes intravenous (IV) access and checks fingerstick glucose		
	Checks for injuries/trauma		
	Assumes unstable cervical spine and places cervical collar		
	Considers that patient may still be seizing		
	Assesses mental status / level of consciousness		
Communication	Calls obstetric and neonatal intensive care unit (NICU) team for evaluation of fetus and possible delivery		
	Calls neurology team for evaluation of possible status epilepticus		
	Calls for gurney to transfer patient from floor to gurney		
Hypoglycemia			
	Identifies hypoglycemia (fingerstick glucose <60)		
	Administers 1 ampule of dextrose 50%		
Airway protection			
	Identifies that patient is hypoventilating.		
	Identifies possible aspiration		
	Decides to intubate patient for airway protection		
	Bag masks patient with cricoid pressure.		
	Intubates patient in a timely fashion		
	May intubate on floor while awaiting gurney		

Table 23.1 (continued)

Transport			
	Ventilates with 100% fraction of inspired oxygen (FiO_2)		
	Avoid hyperventilation (avoid decreasing seizure threshold, avoid uterine hypoperfusion)		
	Administers fluid bolus of 20 cc/kg crystalloid or inotropes/pressors to support uterine perfusion pressure		
	May administer antiepileptics (benzodiazepines, e.g.), after discussion with neurologist		

Summary of Clinical Teaching Points

What are special considerations for managing a Code Blue with a pregnant patient? [1, 2, 3]

- Same Advanced Cardiac Life Support (ACLS) algorithm as any other adult, with some additional considerations.
- It is important to provide left uterine displacement. Ideally, chest compressions are still done on a backboard/hard surface with an extra person providing left uterine displacement by pushing or pulling the abdomen from the right side towards the left.
- Do not forget to consider the second patient: the fetus.
  - Call the Obstetric and Neonatal Intensive Care Unit (NICU) team as soon as possible to initiate fetal monitoring, especially for a viable fetus (>24 weeks estimated gestational age).
  - You may need to prepare for emergent cesarean section.
  - You may need to prepare for neonatal resuscitation should delivery be imminent.

How do you intubate on the ground?

- What are situations where you may need to intubate on the ground?
  - Patient is not located in a hospital room and is at an off-site location: pharmacy, hospital lobby, bathroom, courtyard, entrance to the building, etc.
  - The patient collapsed onto the floor and there is no bed or gurney nearby to move the patient to.
  - The patient is on the floor and is too heavy for providers to readily lift.
- How do you position the patient?
  - Try to optimize intubating position as best as possible, as you would do in the operating room.
  - Use equipment that can be easily found in a hospital: towels, blankets, pillows.

- How do you position yourself for intubation?
  - Kneeling
  - Sitting
  - Sniper
  - Reverse direct laryngoscopy

What is the kneeling position for intubating on the ground?

- Contraindications:
  - There is no room to kneel at the head of the patient.
- Technique:
  - You kneel and hunch forward to perform direct laryngoscopy.
- Challenges:
  - Your view is relatively high up. You have to crouch down to be able to look into the oropharynx.

What is the sitting position for intubating on the ground?

- Contraindications:
  - There is not enough room at the head of the patient to sit.
- Technique:
  - You sit on your bottom with your legs extended on either side of the patient's head.
- Challenges:
  - This relies on upper arm and abdominal strength to be able to perform a good lift for direct laryngoscopy.
  - You're unable to take advantage of body weight mechanics and angles because you're sitting on the floor.

What is the sniper position for intubating on the ground?

- Contraindications:
  - You are pregnant.
  - There is not enough room for you to lie down on the floor.
- Technique:
  - You lie flat on your abdomen/chest and rest your elbows on the ground.
- Challenges:
  - This relies on upper arm and abdominal strength to be able to perform a good lift for direct laryngoscopy.

  - You're unable to take advantage of body weight mechanics and angles because you're lying on the ground.

What is the reverse direct laryngoscopy position for intubating on the ground?

- Utility:
  - This is not an ideal situation, but may be necessary when you cannot physically get to the head of the patient in the standard position. For example, there may be a large orthopedic frame around the bed or the patient may be located in a corner of the room with a wall behind their head and they cannot be moved.
- Technique:
  - You stand on the patient's right side and face them.
  - Scissor the mouth open with your left hand.
  - Perform direct laryngoscopy with your right hand.
  - Lean forward to look into the oropharynx to see your view.
  - Insert the endotracheal tube with your left hand.
- Challenges:
  - This is reverse positioning from what you are accustomed to.
  - Instead of performing a lift forward for direct laryngoscopy, you are pulling backwards away from yourself to lift.

What is status epilepticus? [4, 5]

- Status epilepticus is a single epileptic seizure the lasts more than 5 minutes OR 2 or more seizures occurring within a 5-minute period without the person returning to normal between them.
- What does status epilepticus look like?
  - Generalized tonic clonic (GTC) seizures – obvious, easy to diagnose
  - Non-convulsive status epilepticus – less obvious, may be overlooked

    De novo change in behavior and mental process from baseline
    Prolonged post-ictal confusion after generalized tonic clonic seizure, lasting for at least 30 minutes, associated with continuous epileptiform electroencephalogram (EEG) changes but without major motor signs.
- What is refractory status epilepticus?
  - Status epilepticus that does not respond to initial anticonvulsant treatment with at least: first-line intravenous epileptic drug, benzodiazepines, and one or more second-line antiepileptic drugs, and requiring general anesthetic agents regardless of the delay since seizure onset.

What are unique considerations for status epilepticus during pregnancy? [4, 5]

- When can a seizure occur during pregnancy? A seizure can occur during gestation, labor, or puerperium (within 1 week after delivery of a viable or nonviable fetus).

- Why is a seizure dangerous during pregnancy?
  - Risk to the mother: traumatic falls, aspiration, brain damage, death.
  - Risk to the fetus: compromised placental blood flow resulting in fetal hypoxia.

What is the differential diagnosis for seizure during pregnancy? [4, 5]

- In pregnant women who have seizures in the second half of pregnancy that cannot be clearly attributed to epilepsy, follow existing protocols for eclampsia until a definitive diagnosis is established.
- Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans are safe in pregnancy to assess women presenting with seizures. The risk to the fetus from a single exposure is minimal.
- For pregnant patients with known epilepsy, consider the following causes: antiepileptic drug non-compliance or sub-therapeutic levels; sleep deprivation; pain from labor; fatigue; stress; dehydration.
- If there is uncertainty regarding whether the seizure is due to epilepsy or eclampsia, administer magnesium sulfate until a definitive diagnosis is made.
- Other neurologic causes include: cerebral venous sinus thrombosis, posterior reversible leurkoencephalopathy syndrome, space-occupying lesions, reversible cerebral vasoconstriction syndrome.
- Other systemic causes include: syncope from arrhythmias; aortic stenosis; carotid sinus sensitivity; vasovagal syncope; metabolic derangements such as hypoglycemia, hyponatremia, Addisonian crisis.
- Non-epileptic attack disorder, also known as non-epileptic seizures, dissociative seizures, or pseudo-seizures, may co-exist with epilepsy.

How do you manage status epilepticus in pregnancy? [4, 5]

- Left uterine displacement, to ease pressure of the gravid uterus on the inferior vena cava and thereby improve venous return, cardiac output, and end-organ perfusion.
- Optimize oxygenation and ventilation.
- Consult the inpatient Neurology team.
  - There are limited studies on optimal pharmacologic management of status epilepticus in pregnancy, but in general, benzodiazepines are preferred.

    If there is intravenous access: lorazepam 0.1 mg/kg IV (usually a 4 mg bolus and then repeat dose after 10–20 minutes) OR diazepam 5–10 mg IV slowly.
    If there is no intravenous access: diazepam 10–20 mg rectally and repeat dose 15 minutes later if there is continued suspicion for status epilepticus OR midazolam 10 mg PO buccal.
    If seizures are still not controlled, consider phenytoin 10–15 mg/kg IV loading dose (usually 1000 mg).

- Consult the inpatient Obstetrics team.
  - If there is persistent uterine hypertonus, consider administering tocolytic agents.
  - Initiate continuous fetal monitoring as soon as possible.

    If the fetal heart rate does not improve within 5 minutes or if seizures are persistent, then deliver the baby. This may require emergent cesarean section if vaginal delivery is not imminent.
- Consult the Neonatal Intensive Care Unit (NICU) team.
  - There may be possible neonatal withdrawal syndrome from maternal use of benzodiazepines and antiepileptic drugs.

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Chapter 24
Tetralogy of Fallot (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Review the anatomy of Tetralogy of Fallot.
2. Discuss the intraoperative anesthetic management of Tetralogy of Fallot patients.

Simulator Environment

1. Location: operating room in a children's hospital
2. Manikin setup:
   (a) Age: infant
   (b) Lines: 1 × 24 gauge (G) peripheral intravenous (PIV) line
   (c) Monitors: none on patient at start of case
3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, phenylephrine, albuterol, dopamine, albuterol, fentanyl, midazolam.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 3-lead electrocardiogram (EKG).
   (c) Lines: 24 G and 22 G PIV catheters, intraosseous kit, tourniquet, IV pigtail and flush. No ultrasound available. No vein finder available.
   (d) Crash cart with defibrillator
   (e) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is busy opening trays and making lots of noises in the background during induction.
2. Circulator nurse
   (a) The nurse is helpful but doesn't usually take care of children with congenital heart disease.
3. Surgeon
   (a) The surgeon is on the phone at the computer dictating their operative note from a previous patient.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist starting a case of a 13-month-old, 8 kg baby boy with unrepaired Tetralogy of Fallot presenting for elbow fracture repair.
   (b) Preoperative history: The child was admitted through the ED last night for an elbow fracture sustained after he fell off the couch. He was born at 33 weeks estimated gestational age with unrepaired Tetralogy of Fallot. No recent upper respiratory infection symptoms; meeting all developmental milestones; last ate breast milk 4 h ago. Mom notes that during feedings, patient will turn blue and slow down eating. Sometimes when he's walking, he becomes quiet and squats down for a minute, and then gets up and starts walking again. He is not as active as his older brother running around the house.

(c) Preoperative physical: well-nourished baby sleeping in his mother's arms under a blanket; per parents, a few baby teeth are coming out but nothing loose; breath sounds clear to auscultation bilaterally.
(d) Preoperative vital signs: none
(e) Preoperative labs: none.

2. Scenario development

(a) Phase 1: Tetralogy of Fallot spell during induction

(i) No one in the room is paying attention during induction. Everyone wants to keep a fast pace.
(ii) The patient is initially calm and watching cartoons on the Child Life team's tablet device. When they see the anesthesiologist, they become anxious, tearful, and start crying and turning blue.
(iii) The surgeon asks the anesthesiologist to hurry up and get the patient to sleep. The nurse asks if the anesthesiologist is fine inducing without monitors since the patient is upset.
(iv) The learner should try to calm the patient using midazolam IV since there is a working PIV in place. The learner should place all monitors prior to induction given the patient's congenital heart disease. The learner should try to provide a calm environment (limiting unnecessary noise, distraction tools like tablet devices, toys).
(v) Initial vital signs when monitors are first placed and the child is not yet calm: heart rate 150 s, oxygen saturation (SpO_2) 75%, the non-invasive blood pressure cuff is cycling and unable to obtain a reading because of patient movement.
(vi) Once the child is calmer, vital signs will normalize. The learner may proceed with a combination of IV/mask induction. The learner may administer a fluid bolus concomitantly or prior to induction.

(b) Phase 2: tachycardia from poor pain control

(i) When the surgeons begin to pin, with now increased surgical stimulation, the patient will become tachycardic acutely. Blood pressure will begin to drop quickly, and the patient will begin to desaturate.
(ii) The learner may consider treating with: fluid bolus 20 cc/kg, esmolol 0.25–0.5 mg/kg, phenylephrine 1 mcg/kg.
(iii) The learner should notify the surgeon and ask them to stop stimulating while they treat the hemodynamics.
(iv) Once hemodynamics are more stable, the learner may consider providing better pain control (e.g. fentanyl 1 mcg/kg).
(v) The rest of the case will proceed uneventfully.

Scoring Rubric

Table 24.1 Scoring rubric for case scenario on Tetralogy of Fallot

Topic: Tetralogy of Fallot (Pediatric)			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not completed
Pre-operative evaluation			
History and physical	Obtains set of baseline vital signs.		
	Obtains thorough history about symptoms: episodes of syncope, cyanosis, fatigue, difficulty feeding, poor weight gain, delayed developmental milestones.		
	Obtains history about cardiac workup: recent visit to cardiologist, medications (compliance, up/down-titration of dosing), recent echocardiogram, surgical repair.		
	Performs physical exam: auscultates breath sounds.		
	Confirms in situ PIV is functional.		
Induction			
Preparation	Places monitors prior to induction.		
	Considers providing IV pre-medication (midazolam 0.1 mg/kg, max 2 mg).		
	Considers performing parent induction, if parent is calm.		
	Prepares rescue medications prior to induction: fluid bolus, esmolol, phenylephrine.		
	Attempts to keep child calm and maintain a smooth induction.		
Communication	May perform a huddle pre-induction with the operating room team to discuss potential dangers and backup plans.		
	Avoids tachycardia and hypotension.		
Hemodynamic instability			
	Identifies tachycardia.		
	Treats tachycardia in a timely fashion: crystalloid bolus 20 cc/kg, esmolol 0.25–0.5 mg/kg, phenylephrine 1 mcg/kg.		
	Notifies surgeon and asks them to stop working.		
	Once hemodynamics are stabilized, may consider providing additional pain control (e.g. fentanyl 1 mcg/kg).		

Summary of Clinical Teaching Points

What is Tetralogy of Fallot and how does it occur? [1, 2]

- Tetralogy of Fallot is a type of cyanotic congenital heart disease that develops in utero when the interventricular septum becomes anteriorly and rightward, resulting in 4 key features:
  - Ventricular septal defect
  - Overriding aorta
  - Pulmonary artery obstruction/stenosis/atresia

    Valvular: fixed defect
    Infundibular: dynamic
    Both
  - Right ventricular hypertrophy
- The principles of this are "no flow, no grow." If there is no blood flow in utero, then that part of the heart will not grow. Characteristics that obstruct flow also inhibit growth.

What are Qp and Qs?

- Qp = pulmonary blood flow
- Qs = systemic blood flow
- Blood follows the path of least resistance.
- If pulmonary vascular resistance (PVR) is high and systemic vascular resistance (SVR) is low, then pulmonary blood flow (Qp) decreases and systemic blood flow (Qs) increases. On vital signs, this appears as increased blood pressure but decreased oxygenation, essentially "pumping a lot of blue blood."
- Changing pulmonary vascular resistance may not be helpful in the situation of Tetralogy of Fallot if the type of Tetralogy of Fallot has a fixed pulmonary obstruction.

What do you need to know pre-operatively about Tetralogy of Fallot? [1, 2]

- Cardiac symptoms: presence of hypercyanotic episodes, also known as "Tet spells," syncope, dizziness, lightheadedness, dyspnea.
- Recent echocardiogram, ideally done within the last year or more recently if there's been a change in symptoms.
- Medications: any changes to dosing or frequency or new cardiac medications added.
- Recent Cardiology evaluation.

How do children with Tetralogy of Fallot survive without surgical repair? [1, 2]

- "Squatting:" increases systemic vascular resistance and drives blood from the systemic to the pulmonary circulation via the ventricular septal defect.
- Polycythemia: increases oxygen carrying capacity.
  - Complications: hyperviscosity, stroke, neurodevelopmental delay.
- Dangerous signs and symptoms:
  - Reduced exercise tolerance.
  - Ventricular arrhythmias and sudden death from abnormal right ventricular physiology.

What are the anesthetic goals when caring for a patient with Tetralogy of Fallot? [1, 2]

- Anesthetic goals for Tetralogy of Fallot are similar to hypertrophic obstructive cardiomyopathy (HOCM). HOCM is like the left-sided Tetralogy of Fallot in adults.
- Hemodynamic goals:
  - Support systemic vascular resistance (SVR), to encourage pulmonary blood flow and oxygenation.
  - Augment preload, to augment cardiac output.
  - Support contractility as needed. Over time, the right ventricle becomes hypertrophied and less effective with systolic function.
  - Lower the heart rate to improve diastolic filling time for the hypertrophied right ventricle and improve cardiac output.

What anesthetic techniques can be employed to achieve these anesthetic goals? [1, 2]

Table 24.2 Anesthetic techniques for caring for patients with Tetralogy of Fallot

What to do	How to do it
Keep the child calm pre-operatively and with induction of anesthesia. Avoid tachycardia.	Midazolam 0.5 mg/kg PO. Midazolam 0.1 mg/kg IV. Distractions: child life, parent induction, toys, iPads.
Avoid decreased preload.	Fluid bolus 20 cc/kg crystalloid to augment stroke volume. Caution with surgical insufflation of abdomen/thorax. Caution with peak pressures used for mechanical ventilation.
Treat tachycardia and hypotension as soon as possible.	Esmolol 0.25–0.5 mg/kg – decreases heart rate. Phenylephrine 1 mcg/kg – decreases heart rate and increases systemic vascular resistance.
Avoid hypotension with induction.	Etomidate 0.2 mg/kg. Ketamine 1 mg/kg.
Avoid increases resistance to pulmonary blood flow. Avoid pulmonary infundibular spasm.	Depends on the type of lesion – anatomic pulmonary stenosis cannot be fixed pharmacologically. ↓ PVR: ↓ CO2, ↑ O2, ↑ pH, minimize lung volumes. Avoid catecholamine release: pain, stress, light anesthesia.

Why is it important to avoid the rush to induce and pay attention to the operating room briefing?

- Assume your staff knows nothing.
  - It is your responsibility as the anesthesiologist to advocate for your patient.
  - You set the tone telling everyone that this is not a routine case.
  - Staff needs to pay attention.
  - Staff needs to know how they can help you.
- Consider doing an anesthesia-specific brief before induction.
  - Discuss the high risk of adverse events due to the presence of congenital cardiac disease.
  - Ask for a calm, quiet environment: no phone calls, no opening equipment loudly, no music.
  - Place all monitors on the patient before induction.
  - Know where emergency medications are located and have them pre-drawn.
  - Discuss with staff what could go wrong and how they can help.

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Chapter 25
Emergence Delirium (Pediatric)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Describe the risk factors for emergence delirium.
2. Review the distinguishing signs and symptoms of emergence delirium.
3. Discuss the management of emergence delirium.

Simulator Environment

1. Location: post-anesthesia care unit of a children's hospital
2. Manikin setup:
   (a) Age: infant
   (b) Lines: 24 gauge (G) radial arterial line, 22 G peripheral intravenous (PIV) line in foot, 22 G PIV in hand
   (c) Monitors: 3-lead electrocardiogram (EKG), non-invasive blood pressure (NIBP) cuff, arterial line, pulse oximeter (SpO_2), temperature probe.
3. Medications available: only as ordered by anesthesiologist.
4. Equipment available

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(a) Airway equipment: face mask, Mapleson, oral airway, nasal trumpet, suction.
(b) Crash cart with defibrillator

Actors

1. Post-Anesthesia Care Unit (PACU) nurse
   (a) The PACU nurse is helpful but is a bit distracted because they have another patient about to arrive from the operating room. They are feeling overwhelmed by all the requests from the anesthesiologist. The nurse reiterates that they would feel more comfortable if the anesthesiologist stayed at the bedside longer.
2. Mom/Dad
   (a) Mom/Dad are anxious. They have a newborn at home and everything has been happening so quickly. Their child was just diagnosed with the Wilms tumor 2 weeks ago and they feel overwhelmed.

Case Narrative

1. Scenario background given to participants:
   (a) You are the overnight call anesthesiologist. Your partner anesthesiologist already signed out to you so they could go home. They just dropped off their kid in PACU.
   (b) The sign out is that the patient is a 5-year-old girl who was recently diagnosed with Wilms tumor 2 weeks prior. She had been growing well, no cardiac or pulmonary problems, just some mild asthma with URIs, no inhaler use in >3 months. Mom noticed while bathing her daughter that there was a mass in her belly, so they went to the pediatrician and ended up discovering Wilms tumor.
   (c) The girl just underwent R nephrectomy for Wilms tumor resection. Uneventful induction; easy mask, easy intubation; easy line placement with 2 × PIVs and an A-line. There was a fair amount of bleeding; child received 1 unit of PRBCs 15 cc/kg, with stable vitals at the end of the case. She was extubated in the OR, and taken to PACU on simple face mask. A thoracic epidural had been placed at start of case and loading dose given at end of surgery. PACU RN is waiting for pharmacist to deliver the local anesthetic bag so they can start the epidural infusion.

2. Scenario development

   (a) Phase 1: emergence delirium in PACU.

      (i) The PACU RN calls the learner because the patient seems to be in a lot of pain, and they have already given the maximum number of fentanyl IV doses from the PACU order set. The RN wants to know if there is anything else they can give, perhaps something long-acting like morphine, while they wait for the pharmacist so they can start the thoracic epidural infusion.
      (ii) The learner should go to the bedside to assess the patient. The patient will be tachycardic but there is no NIBP reading and the SpO2 has a poor waveform because the patient won't remain still. She is crying uncontrollably and the parents are anxious and stressed that something is wrong. The parents will comment that their daughter is usually well-behaved and this isn't normal for her to act so wildly. Their daughter won't make eye contact and just keeps screaming, "Get out! Get out! Owww!"
      (iii) The learner may order additional narcotics, which do not calm the patient.
      (iv) The learner should consider emergence delirium, and may give dexmedetomidine, but they will have to leave the PACU and get it from the OR.

   (b) Phase 2: loss of intravenous access

      (i) While the learner is away from the PACU to obtain dexmedetomidine, the patient will remain inconsolable and will manage to pull out their PIV.
      (ii) The learner will need to request assistance from additional providers to help hold the patient still so that they can place a new PIV.
      (iii) The learner may consider administering an intramuscular or intranasal medication to help sedate the child prior to placing a new PIV.

   (c) Phase 3: upper airway obstruction

      (i) With the administration of dexmedetomidine or repeated doses of narcotics, the patient will become calmer and sedated, but will have upper airway obstruction resulting in oxygen desaturation.
      (ii) The learner should intervene by providing supplemental oxygen via simple face mask or Mapleson/face mask.
      (iii) The learner may place airway adjuncts such as an oral airway or nasal trumpet.
      (iv) The learner may provide chin lift or jaw thrust or position the patient in the lateral decubitus position.

Scoring Rubric

Table 25.1 Scoring rubric for case scenario on Emergence Delirium

Topic: Emergence Delirium			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not completed
Emergence delirium			
Evaluation	Obtains history from PACU RN (intraoperative complications, recent medications, temperament preop, pain management).		
	Checks recent vital signs.		
	May check surgical site/wound.		
	Counsels parents about pain management and emergence delirium. Provides reassurance.		
Management	Identifies pain vs. emergence delirium as differential diagnosis.		
	Call for assistance and place new peripheral intravenous (PIV) line in a timely fashion.		
	Communicates well with parents and nurse.		
	Administers analgesic or sedative (fentanyl, dexmedetomidine, propofol, midazolam).		
	Recognizes upper airway obstruction with sedation.		
	Provides supplemental oxygen.		
	Repositions patient to minimize upper airway obstruction (lateral decubitus, oral airway, chin lift).		

Summary of Clinical Teaching Points

What is emergence delirium and how does it present? [1–3]

- Emergence delirium is a transient state of marked irritation and dissociation after discontinuation of anesthesia.
- Children often present as irritable, uncompromising, uncooperative, incoherent, crying inconsolably, moaning, kicking, or thrashing.
- Children often do not recognize familiar objects or people.
- Children often do not respond to consoling measures.
- Parents often report that this behavior is unusual and uncustomary for their child.

What are risk factors for emergence delirium? [1–3]

- Children 2–5 years old after painful procedures under inhalation anesthesia.
- Short-acting volatile anesthetics.
- Rapid emergence from anesthesia.
- Pain is not required. Emergence delirium can occur with sedation for imaging studies. Surgeries with higher postoperative pain do carry a higher risk of emergence delirium.
- Head and neck surgeries such as ear/nose/throat and ophthalmology.
- Pre-operative anxiety.
- Temperament: children who are more emotional, impulsive, less social, less adaptable to environmental changes.

Why is emergence delirium important to address? [1–3]

- Disrupts surgical repair.
- Safety to the child – trauma from thrashing, pulling at lines/drains, and surgical dressing.
- Parental dissatisfaction with child's care.
- Challenging for the PACU staff to manage.
- Increases incidence of new-onset post-operative maladaptive behavioral changes: general anxiety, nighttime crying, enuresis, separation anxiety, and temper tantrums, up to 14 days postoperatively.

How do you prevent and treat emergence delirium? [1–3]

- Weigh acute intervention against the self-limiting nature of emergence delirium.
- Risk of prolonging emergence or delaying discharge from the PACU by administering further sedatives or narcotics.
- Balance with often significant distress to children, parents, and staff members to witness a child in emergence delirium.
- Medication options: alpha-2-agonists such as dexmedetomidine, narcotics such as fentanyl, propofol, ketamine, pre-operative analgesia.

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Chapter 26
Venous Air Embolism (Adult)

Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Discuss risk factors for venous air embolism.
2. Discuss signs and symptoms of venous air embolism.
3. Review intraoperative management of venous air embolism.

Simulator Environment

1. Location: operating room of an adult hospital
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 2 × 18 gauge (G) peripheral intravenous (PIV) lines in the hand and foot, radial arterial line
   (c) Monitors: routine monitors, arterial line, end-tidal carbon dioxide ($ETCO_2$), temperature
3. Medications available: code bag – propofol, etomidate, succinylcholine, rocuronium, epinephrine, phenylephrine, ephedrine.

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4. Equipment available:
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 3-lead electrocardiogram (EKG).
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Crash cart with defibrillator

Actors

1. Neurosurgeons
   (a) The neurosurgeons are concentrated on their operation. It is a large tumor is a well-vascularized location.
2. Scrub tech
   (a) The scrub tech is busy handing instruments to the surgeons.
3. Circulator operating room nurse
   (a) The circulator nurse is busy trying to set up additional surgical equipment.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist taking over in the middle of a case. The patient is a 65-year-old, 80 kg man with type 2 diabetes mellitus, hypertension, hyperlipidemia, and a recently diagnosed, large posterior fossa tumor that was found during workup for nausea, vomiting, and ataxia. The patient had an uneventful induction with fentanyl 850 mcg, propofol 2 mg/kg, and rocuronium 0.6 mg/kg.
   (b) He is currently being maintained on 0.5 MAC sevoflurane and 1:1 N2O:O2.
   (c) Neuromonitoring has reported adequate signals so far.
   (d) The patient is currently positioned prone with the head turned 180 degrees.
   (e) The tumor was reported to be quite large in a vascular location near the confluence of sinuses, but after preoperative discussion with the neurosurgeon and the anesthesiologist who started the case, a decision was made not to place a central line with an air retrieval catheter.
   (f) The anesthesiologist who started the case did place a precordial doppler taped to the back on the left side between the spine and scapula. They turned the volume off/low though because every time they gave a medication or fluid bolus, it made a false whoosh sound that alarmed everyone unnecessarily.

(g) The surgeons have already cut through dura and are now dissecting the tumor, which is noted to be quite vascularized.

2. Scenario development

(a) Phase 1: drop in $ETCO_2$

(i) The patient starts off the scenario hemodynamically stable, HR 70s sinus rhythm, BP 110 s/80s, $ETCO_2$ 35.
(ii) Acutely, the $ETCO_2$ drops from 35 to 25 without any change in ventilator settings.
(iii) The capnogram waveform has a normal tracing.
(iv) The learner should recognize the acute drop in $ETCO_2$ and immediately notify the surgeons.
(v) The learner should ask the surgeons to check their surgical field for possible sites of venous air entrainment.
(vi) The learner should check the precordial doppler and will note there is a sudden loud whooshing sound indicating air passage.
(vii) The learner should move to stabilize the patient:

1. Ventilating with 100% fraction of inspired oxygen (FiO_2).
2. Providing inotropic or pressor support as needed.
3. Ensuring adequate oxygenation and ventilation.

(viii) The learner should move to prevent further entrainment of venous air:

1. Discontinue nitrous oxide.
2. Consider total intravenous anesthetic (TIVA).
3. Ask the surgeons to flood the surgical field with saline.
4. Ask the surgeons to identify any open vessels, in particular venous sinuses.
5. Ask the surgeons to place bone wax on open bone that might entrain air.

(b) Phase 2: right heart failure

(i) The patient will become hemodynamically unstable due to right heart failure. They will become acutely bradycardic and hypotensive.
(ii) The learner should continue to support hemodynamics, particularly with inotropes due to suspected right heart failure. This may include dopamine or epinephrine infusion.
(iii) The learner may ask the surgeons to reposition the patient in a head down position to prevent further entrainment of air from the head to the heart.
(iv) The learner may ask the surgeons to reposition the patient with the right side up to keep air in the right side of the heart.
(v) As the surgeons identify and repair open venous sinuses and the learner provides hemodynamic support, there will be gradual improvement in the hemodynamics.

Scoring Rubric

Table 26.1 Scoring rubric for case scenario on Venous Air Embolism

Topic: Venous Air Embolism			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not completed
Drop in end-tidal carbon dioxide			
Communication	Immediately notifies the surgeon of acute drop in $ETCO_2$.		
	Assumes venous air embolism (VAE) until proven otherwise.		
	Surveys ventilator settings, circuit, and manually bags patient to check for compliance to rule out other cause of drop in $ETCO_2$.		
	Asks the surgeon to survey surgical field for possible sites of venous air entrainment.		
	Checks precordial doppler to confirm VAE.		
	Recognizes whooshing sound on precordial doppler as VAE.		
Management	Ventilates with 100% FiO_2.		
	Discontinues nitrous oxide.		
	Considers total intravenous anesthetic (TIVA).		
	Asks the surgeon to flood the surgical field with saline.		
	Asks the surgeons to identify any open vessels, in particular venous sinuses.		
	Asks the surgeon to place bone wax on open bone.		
	Initiates inotropic or pressor support.		
Right heart failure			
Communication	Identifies hypotension and bradycardia as signs of right heart failure due to large VAE.		
	Notifies surgeon of hemodynamic instability.		
	Calls for help.		
Management	Calls for crash cart.		
	Calls for bed to be brought to room to possibly flip prone to supine for chest compressions.		
	Initiates inotropic support (example: dopamine, epinephrine).		
	May ask the surgeon to position the patient head down to prevent further air entrainment from head to heart.		
	May ask the surgeon to position the patient right side up to keep air in the right atrium and right ventricle.		
	Asks the surgeons to identify and repair open venous sinuses or bone.		

Summary of Clinical Teaching Points

What is a venous air embolism? [1, 2]

- Venous air embolism is entrapment of air or exogenous gas from the operative field or other communication with the environment into the venous or arterial vasculature, resulting in systemic effects.

What types of surgeries pose a higher risk for venous air embolism? [1, 2]

- Neurosurgery cases
  - Elevated positioning of the head relative to the heart, even when a patient is "supine," they may have neck flexion or be in reverse Trendelenburg positioning.
  - High vascularity – tumors, vascular malformations.
  - Many compromised vessels – brain traumas.
  - Dural venous sinuses – venous channels do not collapse easily, so they can entrain air easily.
  - Classically posterior fossa – confluence of sinuses and prone position of the patient.
- Gravitational patient: any surgery where the surgical field is above the level of the heart
  - Example: prostate surgery, where the patient is in steel Trendelenburg positioning.
- Cesarean sections
  - Uterus may be raised above the level of the heart for hemostasis management.
- Placement/removal of internal jugular vein central lines
  - Anxious patient may inhale during removal/exchange of the line, and entrain air into the right heart
- Any procedure where gas can be entrained under pressure into soft tissue, cavities, or vasculature

What determines the severity of a venous air embolism? [1, 2]

The primary factors are the rate and volume of accumulation, as outlined in the table below.

Table 26.2 Factors affecting rate and volume of accumulation of a venous air embolism

High volume of air entrainment	Rate of accumulation
Gravitational gradient – position of patient and height of vein relative to the right side of the heart.	Pulmonary circulation to alveolar interface is a reservoir to dissipate intravascular gas.

(continued)

Table 26.1 (continued)

High volume of air entrainment	Rate of accumulation
What is a lethal volume of air? Adult: 200–300 cc, or approximately 3–5 cc/kg. Neonate: 1 cc/kg (note, the average neonate is 3–4 kg). The closer the vein of entrainment is to the right side of the heart, the smaller the required lethal volume.	Negative pressure gradient versus positive pressure gradient: air being forced in under positive pressure will accumulate faster.
	If the rate of entrainment is slow enough, the heart may be able to tolerate large quantities of air.

How does a venous air embolism cause harm? [1, 2]

- The venous air embolism induces pulmonary hypertension, resulting in right heart failure.
  - It stimulates the release of inflammatory markers from the pulmonary vasculature.
  - Microbubbles form from turbulent flow in the circulation, stimulating platelet aggregation.
  - This induces a systemic inflammatory response.
  - Physical and chemical damage to the pulmonary vasculature results in microvascular permeability, leading to sequelae such as: pulmonary edema, toxic free radical damage, ventilation/perfusion mismatch, and bronchoconstriction.
- The venous air embolism can induce an air lock mechanism.
  - If it is a large enough air embolism, approximately >5 cc/kg, it can create an immediate air lock scenario, resulting in complete obstruction of the right ventricular outflow tract. This causes immediate right heart failure, leading to several complications: decreased cardiac output, hypotension, myocardial and cerebral ischemia, and cardiac arrest.

How do you detect a venous air embolism on your monitors? [1, 2]

- Acute drop in the end tidal carbon dioxide ($ETCO_2$) but you are ventilating but not perfusing the lungs.
  - A change of as little as 2 mmHg $ETCO_2$ can be an indicator of a venous air embolism. For high-risk procedures, you may want to set a low threshold for suspecting venous air embolism.
- Hypotension and changes in the electrocardiogram (EKG)
  - Generally, this reflects an already compromised cardiac status.
  - It is often seen early in the clinical course with rapid entrainment of air.

- Oxygen desaturation
  - This is often a late finding that requires severe physiologic disturbance.
- Why would there be hemodynamic collapse and loss of cardiac output from a venous air embolism?
  - Air lock mechanism: air accumulates in the right ventricle and obstructs the right ventricular outflow tract.
  - The right ventricle distends and compresses on the left ventricle. There is often septal bowing of the interventricular septum. This impairs left ventricular contractility and decreases cardiac output.
  - There is impedance of venous return as well, further decreasing cardiac output.
  - Air goes into the pulmonary circulation, initiating an inflammatory cascade and an acute rise in pulmonary vascular resistance.
  - The right heart goes into acute right heart failure from the acute pulmonary hypertension.

How do you detect a venous air embolism? [1, 2]

- Trans-esophageal echocardiogram (TEE)
  - TEE is the gold standard for detecting a venous air embolism.
  - However, TEE is not always practical, especially in a neurosurgical patient who may be positioned in head flexion, with the table rotated 180 degrees, potentially also in a lateral or prone position.
  - There may be risk of trauma to the larynx or esophagus from prolonged compression of soft tissues during the case.
  - Use of the TEE probe requires some practitioner expertise.
- Precordial Doppler
  - This is cost-efficient and easy to use.
  - It should be positioned along the right of left sternal border, ideally on the chest but may also be positioned at the back.
  - There can be interference and static noise from electrocautery use by the surgeon.
  - There can be artifact also from administration of intravenous medications by the anesthesiologist.
  - You may choose to only increase the volume on the Doppler machine during times where a venous air embolism is more likely to occur (e.g. during dissection around a vascular tumor).
  - In large-breasted women, it may be hard to position well. A roll may be applied to place the precordial Doppler in the inter-mammary location.
- End-tidal nitrogen (ETN_2)
  - ETN_2 is not readily available at most institutions.
  - It would require a significantly sized venous air embolism to cause even a 0.01 level change in the ETN_2.

What is the treatment for venous air embolism? [1, 2]

- 100% fraction of inspired oxygen (FiO_2)
  - Institute high flow oxygen and discontinue nitrous oxide if it is running.
  - Mechanism of hyperbaric oxygen therapy: reduction in the size of air bubbles due to accelerated nitrogen resorption and increased oxygen content of blood.
  - However, hyperbaric oxygen is ineffective if the embolism has already directly entered the cerebral circulation and caused ischemia.
- Positioning
  - Left lateral decubitus position may help relieve the air lock in the right side of the heart, but this maneuver has not been found to help hemodynamics in canine studies. Also, if you find yourself needing to initiate Advanced Cardiac Life Support (ACLS) and start chest compressions, then this is suboptimal.
  - Consider placing the patient with the heart above the location of air entrainment. Example: in a craniotomy, consider placing the patient in Trendelenburg position. However, this may make it challenging for the surgeon to operate and close the vascular source of the air embolus.
  - Support hemodynamics with inotropes and pressors as needed. It is especially important to support the right heart, which is now encountering high resistance to right ventricular outflow and is at high risk of going into acute right heart failure.
- Notify the surgeons
  - The surgeons should try to identify the source of the venous air embolus, which is often vascular.
  - Example: in a craniotomy, the neurosurgeon can flood the surgical field with saline and identify bubbles as a source. They can place bone wax over exposed bone that may be a potential source of air.
- Initiate ACLS as indicated. Perform defibrillation and chest compressions if needed.
- Call for help and get extra providers in the room to help with the resuscitation.
- Consider reducing air entrainment during intracranial surgery by providing transient jugular venous compression.
  - Caution: this may increase intracranial pressure, decrease cerebral venous drainage, and decrease cerebral perfusion.
  - Caution: you may inadvertently compress the carotid artery, resulting in decreased cerebral blood flow, venous engorgement with cerebral edema, carotid sinus stimulation leading to severe bradycardia, and disruption of plaques in the carotid artery causing ischemic stroke.
- Air removal mechanically (see the next question).

How do you remove a venous air embolus? [1, 2]

- Suction out the air. However, this does not treat the current hemodynamics. The air that is causing the problems is not what is being suctioned out. That air has already spread to the right heart and pulmonary vasculature and cannot be retrieved.
- Multiorifice catheter: it is controversial how effective this can be.
  - Ideally, the catheter would be inserted in the right internal jugular vein or the right subclavian vein, and positioned 1 cm above the sino-atrial node.
  - However, it works less than 50–60% of the time and has generally fallen out of favor.
  - It is not often stocked at most institutions.
  - Few providers have experience ever placing one.
  - The success rate of aspiration an appreciable amount of air from a multiorifice catheter is low
  - Options for catheters: Bunegin-Albin multiorifice catheter (success rate of 30–60%), Swan-Ganz catheter (success rate of 6–16%), Cordis with a double lumen slick.
  - Ideally, if you had a high suspicion for a venous air embolism, you would have placed this central line before the start of surgery. Once a venous air embolism has occurred, it is very difficult to place a new central line amidst an ongoing resuscitation.

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Chapter 27
Chronic Obstructive Pulmonary Disease (Adult)

Suraj Trivedi, Matt Mueller, and Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Understand the anesthetic management of patients with severe chronic obstructive pulmonary disease (COPD).
2. Identify the signs of severe obstructive ventilatory defects intraoperatively.
3. Review ventilator management in patients with severe obstructive airway disease such as COPD.

Simulator Environment

1. Location: operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 2 × peripheral intravenous (PIV) lines, Foley catheter.
   (c) Monitors: non-invasive blood pressure cuff (NIBP), 5-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide ($ETCO_2$).
   (d) Medications available: normal saline, propofol, ketamine, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam.
   (e) Equipment available

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(a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
(b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG, radial arterial line.
(c) Lines: arterial line kit, central line kit, PIV kits.
(d) Crash cart with defibrillator.
(e) Paperwork: pre-operative anesthesia history and physical.

Actors

1. Scrub tech
   (a) The scrub tech is busy assisting the surgeon.
2. Circulator nurse
   (a) The nurse is busy locating supplies for the scrub tech.
3. Surgeon
   (a) The surgeons are focused on their operation.

Scenario Development

1. Background
   (a) You are the anesthesiologist taking care of a 65-year-old man with a history of severe COPD who is scheduled for a robotic prostatectomy.
   (b) Past medical history is notable for a 45 pack-year smoking history and morbid obesity, with a body mass index (BMI) of 55.
   (c) Home medications include supplemental oxygen via nasal cannula at 4 L/min at nighttime, budesonide, albuterol, and tiotropium.
   (d) There are no recent labs studies. The patient's chest radiography from 1 month ago was notable for hyperinflated lungs.
   (e) The surgery has already begun. The patient us currently hemodynamically stable and has just been intubated with an endotracheal tube. The patient is currently being maintained under 1 MAC of volatile anesthetic.
   (f) The surgeons have just insufflated the abdomen and have requested that the anesthesiologist place the patient in steep Trendelenburg position.
2. Phase 1: dynamic hyperinflation
   (a) As the learner begins placing the patient in steel Trendelenburg position, the learner will notice that the patient becomes increasingly tachycardic and hypotensive. The oxygen saturation (SpO_2) will slowly start to decline before stabilizing in the mid-80s%.

(b) The learner should perform the following steps:

(i) The learner should communicate directly with the surgeon their concerns for compromised ventilation and hemodynamic instability.
(ii) The learner should examine the ventilator peak pressures, volume curve, and pressure waveform. The learner will recognize that there is significant obstructive ventilatory defect and auto-PEEP occurring.
(iii) The learner should allow the patient to exhale the trapped air as much as possible by either disconnecting the ventilator and allowing passive exhalation, or by increasing the inspiration to expiration (I:E) ratio to prolong expiration time.
(iv) The learner may raise the possibility with the surgeon of performing an open repair to minimize insufflation and intra-abdominal pressures.
(v) The learner may reposition the patient from Trendelenburg to reverse Trendelenburg positioning.
(vi) The learner should then re-calibrate the ventilator to adjust for a prolonged I:E ratio, and adjust PEEP to at least two-thirds of intrinsic PEEP to promote alveolar recruitment and minimize alveolar collapse.

(c) With the release of the hyperinflation and auto-PEEP, the blood pressure will increase, the heart rate will decrease, and the SpO_2 will gradually improve.

3. Phase 2: hypercarbia, upslanted capnogram

(a) The ETCO2 will be elevated in the 50s, the capnogram will be severely upslanted, and peak pressures will be elevated in the mid-40s.
(b) The learner should perform the following steps:

(i) The learner should recognize that there is severe bronchospasm/COPD exacerbation occurring.
(ii) The learner should check their ventilator settings, circuit, ETT, and auscultate for bilateral breath sounds. On auscultation, they will hear loud bilateral inspiratory and expiratory wheezing.
(iii) The learner should administer beta-2-agonists. They may choose to start with albuterol via the ventilator circuit. If they start with albuterol, there will be no improvement.
(iv) The learner should recognize that that albuterol is not effective and should escalate care to systemic beta-2-agonists in the form of low dose epinephrine IV.
(v) The learner may deepen the volatile anesthetic or administer ketamine IV.
(vi) The learner should discuss speak with the surgeon about minimizing operative time or potentially canceling the case to provide time for medical pre-optimization of patient's COPD.
(vii) The learner may place an arterial line to review serial arterial blood gases (ABGs) and evaluate for respiratory acidosis and hypercarbia.

(c) With the administration of epinephrine IV, the bronchospasm will improve: there will be improved tidal volumes for a given driving pressure, the capnogram upslanting will improve, and there will be less wheezing.

Scoring Rubric

Table 27.1 Scoring rubric for case scenario on Chronic Obstructive Pulmonary Disease (COPD)

Topic: Chronic Obstructive Pulmonary Disease			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not completed
Auto-positive end expiratory pressure (PEEP)			
Evaluation	Communicates with surgeons about hemodynamic changes.		
	Examines ventilator pressures and waveforms.		
	Identifies air trapping and COPD exacerbation as the primary problem.		
Management	Disconnects ventilator hoses to allow complete exhalation.		
	Asks the surgeons to stop insufflation.		
	Ask the surgeons to level the patient's bed and place in slight reverse Trendelenburg position.		
	Adjusts ventilator to increase inspiratory to expiratory (I:E) time.		
	Minimizes fraction of inspired oxygen (FiO_2).		
	Sets reasonable positive end-expiratory pressure (PEEP) adjusted to the patient's FiO_2.		
	Sets ventilator to a mode learner feels most comfortable with and minimizes Peak airway pressures and keeps plateau pressures <30 cmH_2O.		
	Discusses with surgeon the possibility of converting to an open surgery or canceling case and optimizing the patient's COPD.		
	May place an arterial line to review serial arterial blood gases (ABGs) and evaluate for respiratory acidosis and hypercarbia.		
Bronchospasm, hypercarbia			
Evaluation	Correctly recognizes severe bronchospasm/COPD exacerbation.		
	Checks ventilator settings, circuit, endotracheal tube (ETT), and auscultates bilateral breath sounds.		
Management	Administers inhaled beta-2-agonist: albuterol via ETT.		
	Administers systemic beta-2-agonist: epinephrine intravenously (IV).		
	Deepens the volatile anesthetic. May administer ketamine IV.		
	Discusses the extubation plan, including potential for prolonged intubation versus intraoperative extubation. Considers extubation to bilevel positive airway pressure (BiPAP). Considers admission to monitored bed such as Intermediate Medical Unit (IMU) or Intensive Care Unit (ICU).		
	May place an arterial line to perform serial arterial blood gases (ABGs).		

Summary of Clinical Teaching Points

What is chronic obstructive pulmonary disease (COPD)?

- COPD is a chronic respiratory condition leading to expiratory obstruction. It is a type of obstructive lung disease. Subtypes include emphysema, chronic bronchitis, and chronic obstructive asthma [1, 2].
- Symptoms include chronic cough, dyspnea, and sputum production.
- Limitation of passive exhalation is measured by a reduction in forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC). COPD is diagnosed when FEV_1/FVC ratio is <0.7 and is irreversible despite bronchodilator therapy. COPD is classified by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) system based on severity of expiratory limitation.
- In the United States, 4.6% of adults have been diagnosed with COPD, and COPD leads to more than 300,000 deaths per year [1].
- Cigarette smoking is the most important risk factor for developing COPD.

What is the underlying pathophysiology in patients with COPD?

- Chronic inflammatory changes lead to tissue destruction and the loss of host defenses, which worsens with increasing disease severity, and leads to scarring, ciliary dysfunction, and mucous hypersecretion. Effects are observed in the small and large airways, lung parenchyma, and pulmonary vasculature.
- Chronic inflammatory changes and airway obstruction leads to air trapping during exhalation and dynamic hyperinflation [1].
- Respiratory system compliance is reduced in most obstructive lung diseases but is actually increased in patients with emphysema due to reduced elastic recoil.
- Alveolar destruction seen in advanced disease prohibits effective gas exchange and leads to arterial hypoxemia. It is determined by a reduced diffusing capacity for carbon monoxide (DLCO) [1–3].
- Chronic hypoxia leads to pulmonary arterial constriction and pulmonary hypertension. Over time, this can lead to right ventricular enlargement and dysfunction, also known as cor pulmonale [1–3].

How do you ventilate a patient with obstructive lung disease?

Table 27.2 Ventilator settings for patients with chronic obstructive pulmonary disease

Ventilator setting	Management
Tidal volume	Initial settings should target low tidal volumes (6–8 mL/kg) to avoid dynamic hyperinflation and air trapping. Patients with emphysema may have higher lung compliance than other obstructive pathologies (e.g. chronic bronchitis), which may require higher tidal volumes (and lower PEEP).

(continued)

Table 27.2 (continued)

Ventilator setting	Management
Respiratory rate	Initial respiratory rate should be 8–10 breaths/min. Due to expiratory flow limitation, longer expiratory times (and shorter inspiratory times) may be required to limit dynamic hyperinflation. Without full expiration, unexpired gas remains in the lungs and leads to dynamic hyperinflation (i.e. air-trapping, breath stacking, auto-PEEP, or intrinsic-PEEP). Lowering the respiratory rate will lengthen the expiratory time.
Positive end expiratory pressure (PEEP)	PEEP may be initially set to 5 cmH_20 and titrated up according to oxygenation but should remain less than intrinsic PEEP. Some argue that PEEP should be set at 2/3 of the intrinsic PEEP. Applied PEEP prevents alveolar collapse and facilitates airway patency, which may limit expiratory flow restriction. In spontaneously breathing patients, applied PEEP may also reduce the effort required to trigger a ventilator breath. However, excess PEEP may worsen air trapping and can be detrimental.
Inspiration to expiration (I:E) ratio	Initially, the I:E should be set to 1:3. However, longer expiratory times may be required.

What complications can arise when mechanically ventilating a patient with COPD?

- Air trapping leads to dynamic hyperinflation as evidenced by increased peak airway pressure, reduced expiratory volume, and a failure of the flow-volume loop to return to baseline at end-exhalation [4].
- Dynamic hyperinflation, when severe, can lead to hypotension and increases the risk for pneumothorax [5].

What is dynamic hyperinflation?

- Dynamic hyperinflation is also termed breath stacking, auto-PEEP, or intrinsic PEEP ($PEEP_i$), where PEEP stands for positive end expiratory pressure.
- When full expiration does not occur, unexpired gas accumulates in the lungs resulting in air trapping.
- Auto-PEEP can be measured on a ventilator by performing an end-expiratory hold.

How do you treat dynamic hyperinflation?

- Inhaled bronchodilators may reduce expiratory obstruction, thereby allowing for full expiration.
- Ventilator changes include: decreasing the respiratory rate or tidal volume (i.e decreasing minute ventilation), decreasing inspiratory time (by reducing the respiratory rate or changing the inspiratory time setting), or by increasing inspiratory flow rate (to reduce inspiratory time) [6].
- PEEP should be set to less than the intrinsic PEEP to prevent alveolar collapse and maintain airway patency, which also serves to reduce expiratory restriction.

- In the spontaneously ventilated patient, applied PEEP may also reduce the patient's work of breathing by reducing the effort required to trigger a ventilator breath.
- When severe, disconnecting the endotracheal tube from the ventilator can allow for full expiration [3–6].

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Chapter 28
Disseminated Intravascular Coagulation (Adult)

Suraj Trivedi, Matt Mueller, and Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Identify the signs and symptoms of disseminated intravascular coagulation (DIC).
2. Review the laboratory markers associated with DIC.
3. Discuss the management of DIC.

Simulator Environment

1. Location: operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 2 × large bore peripheral intravenous (PIV) catheters; central venous catheter in the right internal jugular vein; arterial line in right radial artery.
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter.
   (d) Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, dopamine, phen-

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ylephrine, ephedrine, albumin, lactated ringers, vasopressin, epinephrine, nitroglycerin, norepinephrine.

(e) Equipment available:

(a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), and suction.
(b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
(c) Crash cart with defibrillator.

Actors

1. Scrub tech
   (a) The scrub tech is busy assisting the surgeons.
2. Circulator nurse
   (a) The nurse is busy assisting the surgeons.
3. Surgeon
   (a) The surgeons are focused on their operation.

Scenario Development

1. Background
   (a) The patient is a 78-year-old man who is in the operating room for management of a small bowel obstruction and bowel ischemia. He was recently admitted to the Intensive Care Unit 3 days prior for sepsis due to urinary tract infection and had been on multiple pressors to treat his hypotension. On the morning of surgery, he had nausea, vomiting, abdominal pain, and metabolic acidosis, and was suspected to have a small bowel obstruction and bowel ischemia.
   (b) Currently he is hemodynamically unstable and is requiring uptitration of his norepinephrine and vasopressin infusions: heart rate 105 bpm, blood pressure 79/40, temperature 38.2 °C.
   (c) Past medical history is notable for uncontrolled type 2 diabetes mellitus, end stage renal disease on intermittent hemodialysis, and prior history of colon cancer status post chemotherapy and hemicolectomy.
   (d) Labs from 24 h prior to surgery:
      (i) Arterial blood gas: pH 7.22 / PaCO2 32 / PaO_2 72 / HCO_3 15.
      (ii) Complete blood count (CBC): white blood cell count (WBC) 33, hemoglobin 6.9, hematocrit 29, platelets 80.

(iii) Coagulation studies: partial thromboplastin (PTT) time 29.5 and prothrombin time (PT) 12.5.

2. Phase 1: oozing from catheter sites

(a) The surgical team has started operating and is in the process of exploring the bowel. The learner will notice that the PIV catheter, central line, and arterial line sites are starting to ooze under the dressings.
(b) The learner should ask the surgeon if they are experiencing increased bleeding from the operative site. The surgeons will report increased oozing from the operative site.
(c) The learner should communicate concern that the patient is in DIC, likely secondary to his septic state and the surgeons should attempt to conclude the operation as soon as possible.
(d) The learner should initially stabilize the patient's hemodynamics with the judicious use of fluid management and pressors.
(e) The learner should call for blood products, including packed red blood cells, fresh frozen plasma, platelets, and cryoprecipitate.
(f) The learner should send repeat labs, including complete blood count, coagulation studies, fibrinogen, D-dimer, and thromboelastogram (TEG).
(g) The learner should consider the use of tranexaminic acid in the current hyperfibrinolytic state.
(h) With the initiation of these measures, the bleeding will improve.

3. Phase 2: anticoagulation

(a) Once the bleeding is under control, the learner may discuss with the surgeon the possibility of starting anticoagulation, such as heparin or low molecular weight heparin, to reduce the risk of thrombosis.

Scoring Rubric

Table 28.1 Scoring rubric for case scenario on Disseminated Intravascular Coagulation

Topic: Disseminated Intravascular Coagulation			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not completed
Communication	Informs surgeons that patient is oozing from multiple vascular access sites.		
	Expresses concern that the patient may be in DIC due to sepsis.		
	Asks the surgeons to conclude surgery as soon as safely possible.		

(continued)

Table 28.1 (continued)

Management	Calls for blood products to be brought to the operating room STAT, including packed red blood cells, fresh frozen plasma, platelets, and cryoprecipitate.		
	Supports hemodynamics with fluids, crystalloids, and pressors, as needed, while waiting for blood products to arrive.		
	Sends off repeat laboratory studies, including complete blood count, coagulation studies, fibrinogen, D-dimer, thromboelastogram, and an arterial blood gas.		
	Considers the use of tranexaminic acid to control the hyperfibrinolytic state.		
	Once bleeding is controlled, discusses with surgeon the possibility of starting anticoagulation to prevent thrombosis.		

Summary of Clinical Teaching Points

What is disseminated intravascular coagulation (DIC)?

- The official definition of disseminated intravascular coagulation, according to the International Society of Thrombosis and Hemostasis, is "an acquired syndrome characterized by intravascular activation of coagulation with loss of localization arising from different causes. It can originate from and cause damage to the microvasculature, which, if sufficiently severe, can produce organ dysfunction." [1]
- In normal hemostasis, thrombin balances the procoagulant versus anticoagulant and fibrinolytic versus antifibrinolytic systems.
- When an excess of thrombin is generated secondary to inciting factors, such as sepsis, DIC can result.
- Both the procoagulant and hyperfibrinolytic processes may occur simultaneously in DIC. However, depending on the predominant mechanism, patients will present clinically with either thrombosis or bleeding.
- Bleeding from hemorrhagic DIC can be caused by multiple factors including thrombocytopenia, platelet dysfunction, endothelial damage, interference of the fibrin degradation products with the clot structures, and consumption of clotting factors such as fibrinogen [2].

How does disseminated intravascular coagulation present and what labs help to establish its diagnosis?

- Typical hemorrhagic features of DIC include continued bleeding from venipuncture sites and indwelling catheters, generalized ecchymoses that develop sponta-

neously or with minimal trauma, bleeding from the mucus membranes, and bleeding around surgical sites [3].

- Thrombotic features of DIC include thrombophlebitis developing at unusual sites, respiratory distress syndrome, development of renal impairment, central nervous system disturbances, dermal infarcts, and skin necrosis [1].
- In DIC, fibrinolytic activity is increased. Fibrin degradation product serves as a measure of fibrinolytic behavior. The International Society of Thrombosis and Hemostasis (ISTH) has developed a five point scoring system for DIC with scores of 5 or more indicative of DIC [4].
- Laboratory studies include the following: platelet count, prothrombin time, and partial thromboplastin time (PTT), d-dimer, fibrinogen and fibrin levels. Although not confirmed, a low ADAMTS-13 level in DIC has been linked to organ dysfunction especially renal disorder [5].
- Thromboelastometric results can be quite heterogeneous with impaired fibrinolysis, hypocoagulability, and hypercoagulability being noted [6].

What is the anesthetic management of disseminated intravascular coagulation?

- Management of perioperative bleeding consists of identifying patients at risk of DIC, efficient utilization of lab and point of care testing, use of blood and factor-based concentrate therapies, and finally understanding the limits to therapy.
- Overzealous replacement of deficient procoagulant factors, not paying attention to deficient anticoagulation factors, and reluctance to initiate anticoagulant agents for venous thromboembolism prophylaxis after a recent bleed can transition a coagulopathy state into a hypercoagulable state.
- In bleeding patient, platelets are generally corrected when below 50. In non-bleeding patients scheduled for surgical procedures, platelets below 20 are replaced with transfusion.
- A severe hypo-fibrinogenic state can be treated with a combination of fresh frozen plasma and purified fibrinogen concentrate or cryoprecipitate to maintain fibrinogen levels greater than 1 g.
- The use of tranexamic acid (TXA) in DIC is controversial. Several authors postulate that the late initiation (defined as 3 h from the start of bleeding) of TXA treatment might result in an increased risk of thrombotic events in DIC through inhibition of fibrinolysis. Although DIC often manifests as bleeding, the underlying pathology is that of thrombosis and consumption of clotting factors, which is why TXA should be used with great caution and only reserved for those patients with hyper-fibrinolysis with severe bleeding [7].
- Anti-coagulation therapy with heparin is recommended after control of the overt bleeding phase of DIC and is especially useful for the treatment of embolic complications in a patient with low grade sustained DIC. Prophylactic low molecular weight heparin dosing for deep venous thrombosis prevention mandatory in the intensive care unit [4].

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Chapter 29
Severe Aortic Stenosis (Adult)

Suraj Trivedi, Matt Mueller, and Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Understand the anesthetic management of patients with severe aortic stenosis.
2. Review the signs of intraoperative hemodynamic collapse secondary to aortic stenosis.

Simulator Environment

1. Location: operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 2 × large bore peripheral intravenous (PIV) catheters.
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter.
   (d) Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, dopamine, phenylephrine, ephedrine, albumin, lactated ringers, vasopressin, epinephrine, nitroglycerin, norepinephrine.

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(e) Equipment available:

(i) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), and suction.
(ii) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
(iii) Crash cart with defibrillator.

Actors

1. Scrub tech
   (a) The scrub tech is busy assisting the surgeons.
2. Circulator nurse
   (a) The nurse is busy assisting the surgeons.
3. Surgeon
   (a) The surgeons are focused on their operation.

Scenario Development

1. Background
   (a) The patient is a 55-year-old woman with severe aortic stenosis who is presenting for an emergency open exploratory laparotomy after a motor vehicle accident with a positive Focused Assessment of Sonography in Trauma (FAST) exam and concerns for splenic rupture.
   (b) Due to the emergent nature of the case, you have been unable to elucidate a detailed medical history. However, you are aware of the patient's severe aortic stenosis, uncontrolled type 2 diabetes mellitus, poorly-controlled hypertension, and obesity. You are not aware of any further details regarding the patient's medical conditions, nor have you been able to ask any further questions as the patient was rushed into the operating room.
   (c) The Emergency Department has placed 2 large bore PIVs for access. You are in the operating room and have just induced general anesthesia a few minutes ago. The surgeon is now preparing to begin operating.
   (d) Laboratory studies were drawn and sent by the Emergency Department but the results are still pending when the case starts.
2. Phase 1: tachycardia and hypovolemia.
   (a) The patient's vital signs at the start of surgery will be tachycardia with a heart rate in the 110 s–120 s and hypotension with systolic blood pressure in the 60s–70s.

(b) The learner should communicate to the surgeons that the patient is becoming quite tachycardic and hypotensive.
(c) The learner should check the electronic medical records to see if the recently sent labs have resulted. They will show the following:

(i) Complete blood count: white blood cell 5.5/hemoglobin 6.3/hematocrit 24/platelets 180
(ii) Arterial blood gas: pH 7.19/$PaCO_2$ 30/PaO_2 180/HCO_3 17
(iii) Basic metabolic panel: Na 139/K 3.3/Cl 99/HCO3 17/BUN 25/Cr 0.95/Glucose 203

(d) The learner should raise concern for hemorrhagic shock in the setting of a positive FAST exam and concern for splenic rupture.
(e) The learner should act quickly to place an arterial line for more invasive hemodynamic monitoring.
(f) The learner should initiate Massive Transfusion Protocol. This includes communicating with the surgeons and the nurses to call the Blood Bank.
(g) With placement of the arterial line, the learner should send repeat laboratory studies, including CBC, BMP, coagulation studies, ABG, and type and cross for blood products such as Packed Red Blood Cells (PRBCs) and Fresh Frozen Plasma (FFP).
(h) The learner should administer vasopressors and initiate fluid resuscitation with crystalloids, colloids, and eventually blood products while the surgeons work to control the bleeding.

3. Phase 2: persistent hypotension despite adequate surgical hemostasis.

(a) The surgeons will state that the splenic bleeding is under control with good hemostasis, but there will still be continued hemodynamic variability with a narrowed pulse pressure. This is more pronounced when the patient is tachycardic.
(b) The learner should suspect hemodynamic instability due to undetected surgical bleeding versus the patient's underlying severe aortic stenosis.
(c) The learner should interpret clinical data from more invasive monitors:

(i) Note a low pulse pressure variation from the arterial line, indicating appropriate volume status.
(ii) Place a trans-esophageal echocardiogram, which will show severe aortic stenosis with hypertrophic, normal-filled left ventricle, suggestive of chronic aortic stenosis and adequate trauma volume resuscitation.

(d) The learner should articulate the hemodynamic goals for managing aortic stenosis:

(i) Normal to low heart rate, 60–80 bpm.
(ii) Normal sinus rhythm, cardiovert as needed.
(iii) Normal preload.
(iv) Augment afterload to maintain adequate mean arterial pressures.
(v) Support contractility as needed.

(e) The learner should control the patient's current tachycardia by ensuring appropriate depth of anesthesia, pain control, fluid resuscitation, and pharmacologic management as indicated (example: esmolol, phenylephrine).
(f) The learner will note that the patient's hemodynamic variations decrease with adequate control of the tachycardia.

4. Phase 3: atrial fibrillation

(a) In spite of these interventions, the patient will go into new onset atrial fibrillation with rapid ventricular response, with significant hypotension.
(b) The learner should call for the crash cart and call for help.
(c) The learner should notify the surgeons of the need for emergent cardioversion.
(d) The learner should perform synchronized cardioversion in a timely fashion to restore normal sinus rhythm.
(e) The learner may also administer amiodarone 150 mg and may start an amiodarone infusion 1 mg/min.

Scoring Rubric

Table 29.1 Scoring rubric for case scenario on Severe Aortic Stenosis

Topic: Aortic Stenosis			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not completed
Hypovolemia			
Communication	Informs surgeon of patient's hemodynamic instability.		
	Inquires about current level of surgical hemostasis.		
	Raises concern for hemorrhagic shock.		
	Asks nurse to call Blood Bank to initiate Massive Transfusion Protocol and notifies surgeon of this.		
Management	Checks electronic medical records for lab results.		
	Correctly interprets CBC, ABG, and BMP.		
	Places an arterial line in a timely fashion.		
	Initiates Massive Transfusion Protocol (MTP).		
	Sends repeat labs, including CBC, BMP, coagulation studies, ABG, and type and cross for PRBCs and FFP.		
	Fluid resuscitates with crystalloids and colloids.		
	Transfuses blood products in balanced ratio.		

Table 29.1 (continued)

Aortic stenosis			
Communication	Inquires about current level of surgical hemostasis again – raises possibility of undetected surgical bleeding.		
Management	Correctly interprets pulse pressure variation on arterial line.		
	Performs a trans-esophageal echocardiogram (TEE) in a timely fashion.		
	Correctly interprets the TEE images: severe aortic stenosis, left ventricular hypertrophy, normal volume status.		
	Correctly identifies hemodynamic goals for aortic stenosis: normal to low heart rate; normal sinus rhythm; normal preload; augment afterload; support contractility as needed.		
	Treats the sinus tachycardia: depth of anesthesia, pain control, fluid resuscitation, pharmacologic (e.g. esmolol, phenylephrine).		
Atrial fibrillation			
Communication	Calls for the crash cart.		
	Calls for help.		
	Notifies the surgeon of the arrhythmia and the need for emergent cardioversion.		
Management	Identifies atrial fibrillation rhythm correctly.		
	Performs synchronized cardioversion in a timely fashion. May start at 120 J and uptitrate as needed or may start at 200 J.		
	Administers amiodarone loading dose of 150 mg; may start an amiodarone infusion of 1 mg/min.		

Summary of Clinical Teaching Points

What is aortic stenosis?

- Aortic stenosis is the most common cause of left ventricular outflow obstruction.
- Aortic stenosis can be divided into congenital, rheumatic, and degenerative.
- Degenerative (or calcific) changes are the most common form of aortic stenosis, with mechanical stress leading to fibrosis and calcification. Initially, this process starts as sclerosis with uneven thickening that does not obstruct the left ventricular outflow tract. If degenerative changes continue, it can progress to calcific stenosis.
- Risk factors for degenerative stenosis include type 2 diabetes mellitus, hypercholesterolemia, smoking, hypertension, and chronic renal failure.

- Congenital bicuspid aortic valve is the most common congenital cardiac malformation and results in turbulent flow, fibrosis, and calcification of the valve opening [1, 2].

What is the pathophysiology and clinical presentation of aortic stenosis?

- Normal aortic valve area is 2.6–3.5 cm^2 in adults.
- Significant hemodynamic changes occur when the aortic valve area is below 1 cm^2.
- In response to a narrowing of the aortic valve area, the left ventricle hypertrophies, allowing itself to maintain the pressure gradient across the aortic valve. However, increasing ventricular hypertrophy over time can result in diastolic dysfunction and a reduced compliance.
- As the left ventricle hypertrophies, the left atrium also starts to increase in size, with the left atrium's contribution to end diastolic volume increasing from the normal 20–40%. Patients who are not in normal sinus rhythm are at risk of compromising their cardiac output because they lose diastolic filling.
- As left ventricular wall mass increases, left ventricular oxygen requirements increase. Low aortic pressure combined with a high left ventricular end diastolic pressure results in a mismatch between oxygen supply and demand.
- Patients with aortic stenosis can present with angina, dyspnea, or syncope. Angina develops when myocardial oxygen demand is greater than supply in the hypertrophied muscle. The increased metabolic and cardiovascular demands from exercise in patients with a relatively fixed cardiac output can result in syncope. Late findings in severe aortic stenosis include dyspnea at rest or on exertion, paroxysmal nocturnal dyspnea, and pulmonary edema.
- On physical exam, patients with aortic stenosis present with a harsh peaking late systolic murmur at the 2nd intercostal space.
- Electrocardiogram (EKG) evidence of left ventricular hypertrophy presents with t wave inversions or ST segment depression. Extension of calcific infiltrates from the aortic system into the conduction system can result in intra-ventricular blocks. In severe aortic stenosis, lateral views on chest radiograph can show calcific valvular deposition [1, 3].

How is aortic stenosis classified?

- Aortic stenosis is classified as mild, moderate, or severe based upon aortic valve area and mean pressure gradient.

Table 29.2 Classification of aortic stenosis severity

Classification	Aortic valve area (cm^2)	Mean gradient (mm hg)
Mild	1.2–1.8	12–25
Moderate	0.8–1.2	25–40
Severe	0.6–0.8	40–50

- Echocardiography can be used to calculate leaflet thickening, mobility, and evidence of calcification. Continuous wave doppler readings are obtained from blood flow in the left ventricular outflow tract. The maximum velocity used to calculate the maximum pressure gradient across the valve is equal to four times the velocity when measure in meters per second.
- The cross-sectional area of the outflow tract (LVOT) is assumed to be circular and calculated from the diameter. Tracing around the velocity envelopes allows for calculation of the velocity time integral (VTI) as well as the maximum and mean pressure gradients [1, 4]. By re-arranging the continuity equation, the aortic valve area can be obtained.

What are the principals of anesthetic management in patients with aortic stenosis?

- Even asymptomatic patients with systolic ejection murmurs may have significant aortic stenosis. If possible, non-emergent surgery should be delayed for preoperative echocardiographic studies.
- Once the patient has been fully assessed, it is important to determine whether aortic valve replacement surgery is of greater importance than the scheduled, non-cardiac, non-emergent surgery.
- Invasive hemodynamic monitoring with an arterial line placed prior to induction of anesthesia is critical to be able to rapidly detect changes in blood pressure.
- Hypotension leads to myocardial ischemia with a decrease in contractility, thus further reducing blood pressure and coronary perfusion resulting in a downward spiral.
- Maintaining systemic vascular resistance and tone with a vasopressor is important. Examples of possible vasopressors include norepinephrine and phenylephrine.
- It is important to maintain sinus rhythm for adequate ventricular filling and intravascular tone. Unstable or new onset atrial fibrillation requires cardioversion to convert back to normal sinus rhythm. Sinus tachycardia can also be quite detrimental with reduced diastolic filling time reduced and compromised myocardial perfusion [1, 5].

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Chapter 30
Extracorporeal Membrane Oxygenation (Adult)

Suraj Trivedi and Matt Mueller

Case Outline

Learning Objectives

1. Understand the intraoperative anesthetic management of veno-arterial extracorporeal membrane oxygenation (VA-ECMO).
2. Review common VA-ECMO problems and their management, especially low flow (clotting) states, hypovolemia (suction events), and North South syndrome.
3. Discuss the basic components of the ECMO machine.

Simulator Environment

1. Location: operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 1 × large bore peripheral intravenous (PIV) catheter, right internal jugular central venous catheter, right radial arterial line, left sided trialysis catheter, bilateral femoral VA-ECMO catheters, and Foley catheter.
   (c) Monitors: non-invasive blood pressure (NIBP) non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide ($ETCO_2$).

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(d) Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, dopamine, phenylephrine, ephedrine, albumin, lactated ringers, vasopressin, epinephrine, nitroglycerin, norepinephrine.
(e) Equipment available:

(i) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), and suction.
(ii) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
(iii) Crash cart with defibrillator.
(iv) ECMO machine.

Actors

1. ECMO perfusionist
2. Cardio-thoracic surgeon
3. Circulating nurse
4. Scrub tech

Scenario Development

1. Background

(a) The patient is a 25-year-old woman with congenital hypoplastic left heart syndrome, status post Norwood, Glenn, and Fontan procedure as a child. She recently underwent a combined heart and lung transplant 3 days ago. The patient was difficult to wean off cardiopulmonary bypass in the operating room. She was brought to the Intensive Care Unit (ICU) on ECMO support with her chest still open.
(b) The patient has now returned to the operating room for a repeat sternal washout and chest closure. She is currently on VA-ECMO with flows at 4 L/min, 2900 rotations per minute (rpm), sweep 3 L/min, and 50% fraction of delivered oxygen (FdO_2). Systemic heparin was stopped 12 h ago due to ongoing mediastinal bleeding.
(c) Pre-operative laboratory studies:

(i) Arterial blood gas (ABG): pH 7.34/P_aCO_2 39/P_aO2 180/HCO_3 23.
(ii) Complete blood count (CBC): white blood cell count (WBZC) 8/hemoglobin (Hb) 8.1/hematocrit (Hct) 29/platelets 110.

2. Phase 1: hypotension due to suction event.
   (a) The learner has just helped to transfer the patient over to the operating table, connected the patient's endotracheal tube to the anesthesia ventilator, and has started the fresh gas flows and total intravenous anesthetic (TIVA).
   (b) The learner should perform a TIVA rather than use inhaled anesthetic agents. When asked to explain their choice of anesthetic, the learner should explain that while on ECMO, the oxygenator is often unable to adequately filter through volatile anesthetic agents, therefore a TIVA method is often required to ensure an adequate depth of anesthesia.
   (c) The learner will notice now that the patient has become acutely hypotensive, with systolic blood pressure (SBP) in the 60s–70s.
   (d) As the surgeons start the mediastinal washout, the patient will continue to become hypotensive with mean arterial pressure (MAP) in the mid-50s.
   (e) The learner will note that the ECMO circuit is beginning to "chatter."
   (f) The ECMO perfusionist will inform the learner that ECMO flows are starting to decrease.
   (g) The learner should recognize that this is a suction event.
   (h) The learner should immediately instruct the ECMO perfusionist to decrease the rotations per minute (rpms).
   (i) The learner should simultaneously immediately begin volume resuscitation with fluids.
   (j) The learner should suspect bleeding as a cause of the hypovolemia, given the history of ongoing mediastinal bleeding in the ICU.
   (k) The learner should check a repeat ABG, looking specifically at the Hb/Hct to evaluate for anemia.
   (l) The learner should communicate with the surgeon their concerns for hypovolemia due to bleeding. The surgeons will then report that there is increased bleeding at the surgical site.

3. Phase 2: bleeding and North South Syndrome.
   (a) The ABG will show a Hb 6.7/Hct 26.
   (b) The learner should transfuse blood. Blood transfusion will result in cessation of the ECMO chatter.
   (c) The learner should check a repeat ABG to evaluate improvement in anemia.
   (d) Repeat ABG will show the following: pH 7.15/$PaCO_2$ 65/P_aO_2 50/HCO_3 18.
   (e) The learner should identify this as North South Syndrome, likely due to decreased flows and an improving cardiac function while pulmonary function remains poor.
   (f) The learner should communicate concerns for North South Syndrome to the cardiothoracic surgeon and the ECMO perfusionist.
   (g) The learner should also perform one of the following interventions: (a) increase the ECMO flows; (b) decrease cardiac inotropy; or (c) concert to veno-arterio-venous ECMO (VAV-ECMO). The learner should also ensure that preload and afterload are adequately optimized.

4. Phase 3: clotting in the ECMO circuit.
   (a) While the surgeons are closing the chest, the ECMO perfusionist will notice that the flows are once again starting to decrease while the pressure valves have slowly been increasing.
   (b) The learner should suspect a possible clot within the oxygenator or one of the ECMO lines.
   (c) The learner should ask the ECMO perfusionist to check the oxygenator and tubes. At this point, the ECMO perfusionist will notice clots.
   (d) The learner should notify the surgeons and ask them to change out the ECMO tubing.
   (e) The surgeons will work quickly to replace the ECMO tubing and remove the clot.
   (f) The flows, rpm, and pressure values will soon normalize.

Scoring Rubric

Table 30.1 Scoring rubric for case scenario on Extracorporeal Membrane Oxygenation (ECMO)

Topic: Extracorporeal Membrane Oxygenation (ECMO)		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not completed
Suction event		
Performs total intravenous anesthetic (TIVA) instead of using inhaled anesthetic agents.		
Identifies the occurrence of a suction event.		
Asks the ECMO perfusionist to decrease the rotations per minute (rpms).		
Initiates volume resuscitation with fluids.		
Identifies bleeding as a cause of the hypovolemia.		
Sends repeat arterial blood gas (ABG) to evaluate for anemia.		
Communicates their concerns to surgeon for hypovolemia due to bleeding.		
North South Syndrome		
Identifies anemia and initiates blood transfusion.		
Checks serial ABGs to evaluate improvement in anemia.		
Interprets the ABG as evidence of North South Syndrome.		
Communicates with the surgeon the suspicion for North South Syndrome.		
Performs one of the following: (a) increase the ECMO flows; (b) decrease cardiac inotropy; or (c) concert to veno-arterio-venous ECMO (VAV-ECMO).		
Ensures optimization of preload and afterload.		

Table 30.1 (continued)

Clotting		
Suspects possible clot within the oxygenator or one of the ECMO lines.		
Asks the ECMO perfusionist to check the oxygenator and tubes.		
Notifies the surgeons about the presence of clots in the ECMO circuit and asks the surgeons to change out the tubing.		

Summary of Clinical Teaching Points

What is extracorporeal membrane oxygenation (ECMO)? [1]

- ECMO stands for extracorporeal membrane oxygenation and is used to support circulatory or respiratory function, or both circulatory and respiratory function, depending on the configuration.
- ECMO serves as a bridge to long-term support devices such as ventricular assist devices or to transplant (heart or lung), or to allow time for the body to heal.
- ECMO-CPR or ECPR, where CPR stands for cardiopulmonary arrest, is a form of ECMO used during refractory cardiac arrest. Patients meeting specific criteria are initiated on ECMO while CPR is ongoing.
- Intraoperative ECMO is increasingly used during lung transplantation and may be associated with increased survival.

What are the different types of ECMO? [1–3]

- Veno-venous (VV) ECMO provides respiratory support when the native lungs are functioning sub-optimally.
- Veno-arterial (VA) ECMO provides circulatory support when cardiac function is unable to provide adequate tissue oxygenation. It also provides respiratory support if needed.
- Veno-arterial-veno (VA-V) ECMO is a form of VA-ECMO where an additional venous cannula is placed to deliver oxygenated blood into the right atrium.

What are indications for ECMO? [1, 4]

- Indications for ECMO include acute severe respiratory or cardiac failure that has a high risk for mortality (>80%) and is non-responsive to conventional therapy.
- The underlying condition must be reversible or be able to be treated with transplant or a permanent support device.
- Indications for VV-ECMO include:
  - Hypoxemic respiratory failure

    $PaO_2/FiO_2 < 100$ on $FiO_2 > 0.9$ and/or Murray Injury Score 3–4
  - Hypercapnic respiratory failure

    pH <7.20 despite best-practice therapies

- Indications for VA-ECMO include:
  - Refractory cardiogenic shock: failure ≥2 inotropes and/or a mechanical circulatory device, such as an Impella device.
  - Refractory cardiac arrest, where return of spontaneous circulation (ROSC) is not achieved within 10 minutes.
  - As a bridge to recovery of cardiac function, placement of a permanent support device (e.g., ventricular assist device), or organ transplantation.

What conditions may benefit from VV-ECMO? [1, 3]

- Acute respiratory distress syndrome (ARDS)
- Status asthmaticus, or another severe obstructive lung disease
- Acute graft failure following lung transplantation
- Pulmonary contusion

What conditions may benefit from VA-ECMO?

- Refractory cardiogenic shock
- Acute fulminant myocarditis
- Massive pulmonary embolism
- Acute graft failure following heart transplant
- Overdose with cardiac depressant

What are some contraindications to initiating ECMO? [4]

- Advanced age
- Severe/irreversible neurologic function
- Post bone marrow transplant
- Contraindication to anticoagulation (e.g., hemorrhage)
- Disease or condition that is not reversible or there is no alternative long-term intervention available
- Significant comorbid disease (e.g., metastatic disease)
- Significant concomitant organ failure (e.g., cirrhosis, renal failure) and the patient is not a candidate for organ transplantation
- Severe obesity

What are the major parts of the ECMO circuit? [1, 2, 5]

- Cannulas
  - Inserted centrally (e.g., right atrium or ascending aorta) or peripherally (e.g., femoral vessels, axillary artery, etc.).
  - Single stage cannulas have a single hole at the distal tip of the cannula and are typically used for arterial cannulation.
  - Multi-stage cannulas have a single hole at the distal tip of the cannula and multiple holes along the length of the cannula to facilitate increased venous drainage. Multi-stage cannulas are typically used for venous cannulation.
  - Cannulas may be single or double lumen.

  - Tubing is composed of polyvinyl chloride (PVC) and has a biocompatible coated surface.

- Oxygenator
  - Hollow fiber membrane where gas is exchanged by diffusion.
- Pump
  - Promotes flow from the patient, through the oxygenator, and back to the patient.
  - Centrifugal pump (most common) generates a pressure differential within the circuit and is influenced by preload and afterload.
  - Roller pumps exist in some circuits but are not as commonly used.
- Flow Sensor
  - Assesses the blood flow through the circuit and may be integrated into the ECMO machine or may exist as an accessory device.
  - Estimates the hemoglobin, hematocrit, and oxygen saturation of blood passing through the circuit.
  - Bubble detector can sense when air is present within the circuit.
- Pressure Sensor
  - Pressure sensors include the pre- and post-oxygenator pressure sensors and the venous access pressure sensor.
  - Venous access pressure sensor is displayed as a negative value.
  - Post-oxygenator pressure reflects resistance to flow downstream of the oxygenator.
  - Pre-oxygenator pressure reflects resistance to flow downstream to the sensor. This includes resistance within, as well as downstream to the oxygenator. The pressure obtained by the pre-oxygenator sensor is used to calculate the delta membrane pressure.
- Heat Exchanger
  - A warm water bath ensures that blood passing through the circuit is maintained at an appropriate temperature. This can be used to cool a patient after arrest or maintain normothermia.
- Gas Blender
  - Mixes oxygen and air to maintain a specific FiO_2 in the returned blood.
- Dual Flowmeter
  - Also known as the sweep gas flow.
  - Regulates gas flow supplied to the oxygenator membrane and influences carbon dioxide elimination. The flow determines decarboxylation.

- Monitor
  - In-line monitoring of blood gas.

How does ECMO work? [5, 6]

- Deoxygenated blood is removed from the patient via the venous cannula and passes through the oxygenator where supplemental oxygen is supplied and carbon dioxide is removed, and is then returned to the patient via the return cannula.
- Total oxygen delivery (DO_2) is equal to the sum of the oxygen delivered from the ECMO circuit ($D_{ecmo}O_2$) and O_2 from the native pulmonary circulation.
- VV-ECMO [5]
  - Operates in series with the native circulation.
  - Oxygenated blood from the ECMO circuit enters the right atrium where it mixes with deoxygenated blood returning from the systemic circulation. This blood then passes through the pulmonary circulation to the left ventricle where it can be pumped throughout the body via native cardiac function.
- VA-ECMO
  - Operates in parallel to the native circulation.
  - Deoxygenated blood from the right atrium is removed via the ECMO drainage cannula or enters the pulmonary circulation. The oxygenated blood is returned to the systemic circulation, either, by the left ventricle or the ECMO return cannula.
- Carbon Dioxide removal
  - CO2 is cleared from the patient via the membrane lung and is a product of sweep gas flow and the gradient across the membrane.

What can be set on the ECMO circuit? [7–9]

- Setting the rotations per minute (RPM) allows for adjustment of the blood flow through the circuit.
- The fractional oxygen delivered concentration (FdO_2) can be titrated from 21% to 100%.
- The sweep gas flow can be titrated from 0 to 10 liters per minute where increasing flow rates facilitate increased CO_2 clearance.

How is oxygen delivery and consumption assessed? What are important formulas to know? [9–11]

- Under normal circumstances, oxygen delivery is proportional to oxygen extraction.
- Oxygen delivery (DO_2) is reduced when cardiac output (CO) or the arterial oxygen content (CaO_2) are also reduced.
  - Cardiac output is reduced in hypovolemia and cardiac failure.
  - CaO_2 is reduced in anemia or hypoxemia.

- Oxygen consumption (VO_2) is increased in the setting of increased metabolic demand.
- Cardiac output can be measured by thermodilution using a pulmonary artery catheter or calculated with the Fick equation.
- Arterial oxygen saturation should be assessed via a right-sided upper extremity arterial catheter (e.g., radial, brachial, or axillary artery) as this region will be the most sensitive to changes in native cardiac function.
- Useful equations
  - $CaO_2 = 1.34 \times \text{hemoglobin concentration} \times SaO_2 + (0.0031 \times PaO_2)$

    SaO_2: arterial oxyhemoglobin saturation
    PaO_2: partial pressure of arterial oxygen
  - $CvO_2 = 1.34 \times \text{hemoglobin concentration x } SvO_2 + (0.0031 \times PvO_2)$

    SvO_2: mixed venous oxyhemoglobin saturation
    PvO_2: partial pressure of venous oxygen
  - $DO_2 = CO \times CaO_2$
  - CO = Oxygen consumption (VO_2)/(10 × AV oxygen difference)
  - AV oxygen difference = $CaO_2 - CvO_2$
  - $VO_2 = CO \times (CaO_2 - CvO_2)$
  - Oxygen extraction ratio = $(CaO_2 - CvO_2)/ CaO_2$

What anticoagulation strategies are used in patients on ECMO?

- Anticoagulation is necessary in patients on ECMO due to an increased risk of thrombosis with blood flow through the circuit. The risk of thrombosis increases with decreasing ECMO flow rates.
- Unfractionated heparin is the most common anticoagulant used in patients on ECMO and should be monitored based on institutional protocols.
- Maintain the ACT at 1.5 times normal.
- In patients with bleeding complications, anticoagulation can be temporarily paused but flows must be maintained at greater than 3 L/min to prevent thrombosis.

What are common problems encountered on ECMO? How can these problems be classified and treated?

- ECMO is by no means a benign intervention; many complications have been reported in the literature. Here, we divide the complications into those affecting the preload or afterload, and those specific to the circuit.

Problems with preload [9–11]

- Hypovolemia is the most common problem impacting preload in the patient on ECMO.
  - Chattering is often the first sign of hypovolemia. Chattering is the shaking of the ECMO tubing and is caused by the intermittent collapse of the vena cava against the side ports of the venous cannula.

  - As hypovolemia progresses, blood flow through the circuit may be reduced requiring an increase in RPM to achieve the target flow rate. An increasingly negative venous pressure may also be observed.
  - When hypovolemia results in flows outside of the prespecified range, the ECMO circuit will alarm notifying the user of the low flow state.
  - Hypovolemia is mitigated by administering volume (e.g., crystalloid, colloid, or blood products).

- Pneumothorax and cardiac tamponade are manifested by a reduction (or loss) in circuit flow, and may not result in the typical signs observed (e.g. hypoxia, respiratory distress, elevated central venous pressure, etc.).
  - Cardiac tamponade is a relatively rare event occurring in less than 1% of all patients on ECMO, but may occur in more than 40% of patients following cardiotomy.
  - Pneumothorax and cardiac tamponade are easily identified with point of care ultrasonography.
  - Identification of a pneumothorax or cardiac tamponade should be discussed with the surgical team for prompt intervention.

- In summary, if the ECMO flow is reduced a trial of intravenous fluids is warranted while evaluating for possible etiologies.

Problems with the pump

- The incidence of circuit failure has been described in the literature occurring as much as 30% and may be due to mechanical complications including the pump, oxygenator, or due to tube rupture. All of which can be catastrophic.
- Clotting within the pump or oxygenator is a frequent cause of a failing device and requires device replacement to remedy. Visual inspection of the oxygenator may reveal a fibrin clot that appear as dark spots that are more likely found in areas of low flow.
- Oxygenator failure is identified by an increasing delta pressure, where the delta pressure is equal to the pre-oxygenator pressure minus the post-oxygenator pressure (ΔP = pre-oxygenator pressure - the post-oxygenator pressure).

Problems with afterload

- Retrograde aortic flow during ECMO results in increased left ventricular (LV) afterload and may impair myocardial recovery depending on native function and ECMO flow.
- Increased LV afterload may result in increased LV end-diastolic pressure, left atrial pressure, and pulmonary capillary wedge pressure, and may severely impair the LV ejection fraction. Clinically significant elevations in LV afterload may manifest as left ventricular dilation, pulmonary edema, poor exchange, and reduction in the pulmonary arterial catheter and end tidal capnography waveforms.
- Reducing ECMO flow will reduce LV afterload, but may not be feasible in patients with severely depressed cardiac function who rely on higher flows.

These patients will require mechanical unloading with the placement of an intra-aortic balloon pump, Impella, atrial septotomy, direct LV cannulation, or pulmonary artery- or left atrial drain.

What is North-South Syndrome?

- Also known as Harlequin syndrome, occurs in patients on VA-ECMO when poorly oxygenated blood is pumped from the left ventricle and supplies the brain, myocardium, and upper extremities while oxygen-rich blood supplies the lower extremities. In severe cases this results in cyanosis and hypoxia of the upper body while the lower experiences hyperoxia and appears well-perfused.
- Oxygenated blood returns to the patient via retrograde flow into the aorta and mixes with blood that is ejected from the left ventricle. The location of mixing (i.e. the watershed region) is dependent on ECMO flow and native cardiac function, and may occur as cardiac function improves.
- When mixing occurs in the aorta distal to the takeoff of the brachiocephalic, left common carotid, or left subclavian arteries, blood flowing through these arteries originates from the left ventricle as opposed to the ECMO oxygenator. And in patients with impaired pulmonary function (e.g. pulmonary edema, intrinsic disease, etc.), this poorly oxygenated blood will supply the brain and upper extremities leading to hypoxemia in the brain, myocardium, and upper extremities.
- This can be treated by placing an additional venous cannula to deliver oxygenated blood to the right atrium (VA-V ECMO)

Explain the principals of Anesthetic management for patients on ECMO? [12]

- *In vitro* data are equivocal whether circulating levels of analgesia and sedative medications are reduced in patients on ECMO. These patients may require empirically increased medication doses to maintain adequate analgesia and sedation.
- Solely relying on inhaled volatile agents is generally not preferred in patients on ECMO as the gases will not pass through the oxygenator membrane in a consistent manner.
- Thus, using a combination of inhaled and IV anesthetic medications in the operating room will ensure adequate anesthesia.

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Chapter 31
Transfusion Reaction (Adult)

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Case Outline

Learning Objectives

1. Understand the difference between acute versus delayed transfusion reactions.
2. Identify the clinical signs and symptoms of patients experiencing a transfusion reaction while under general anesthesia.
3. Review the various types of acute versus delayed transfusion reactions.

Simulator Environment

1. Location: operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 2 × large bore peripheral intravenous (PIV) catheters, radial arterial line.
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide ($ETCO_2$).
   (d) Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, dopamine, phen-

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ylephrine, ephedrine, albumin, lactated ringers, vasopressin, epinephrine, nitroglycerin, norepinephrine.

(e) Equipment available:

(i) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), and suction.
(ii) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
(iii) Crash cart with defibrillator.

Actors

1. Surgeon
2. Circulating nurse
3. Scrub tech

Scenario Development

1. Background

(a) The patient is a 67-year-old woman who is undergoing a posterior laminectomy from T4 to L3 with interbody fusion.
(b) Past medical history is notable for scoliosis, obesity, and type 2 diabetes mellitus on home insulin.
(c) The patient is now several hours into surgery and the surgeons report that she has been slowly oozing from her operative site.
(d) Serial arterial blood gases (ABGs) show a gradually downtrending hemoglobin (Hb), with the most recent Hb 8.2.
(e) She has received 3 l of crystalloid and 1 l of 5% albumin. Estimated blood loss so far is 2 l.

2. Phase 1: hypotension and tachycardia, blood transfusion

(a) The learner starts this scenario in the operating room, several hours into the surgery. The surgeon will report that the surgery is proceeding well and there is continued slow oozing from the surgical site. Hemodynamics have remained stable with resuscitation with crystalloids and colloids.
(b) The learner will notice that the patient is starting to become tachycardic and mildly hypotensive.
(c) The learner should treat with fluids and administer a low dose vasopressor to stabilize the hemodynamics.
(d) The learner should suspect hypovolemia. They should investigate by walking around the operating room to check the number of blood-soaked gauzes and wet laps, blood in the drapes and surgical field, and blood in the suction canister.

(e) The learner should also send a repeat ABG to evaluate for anemia.
(f) If the learner does not send a repeat ABG, the patient will become increasingly hypotensive and tachycardic.
(g) Eventually the surgeon will also comment on the increased blood loss in the surgical field.
(h) Repeat ABG will show the following: pH 7.25/P_aCO_2 34/P_aO_2 180/HCO_3 20, with Hb 6.7.
(i) The learner should call for blood products with the goal of transfusing a balanced ratio of packed red blood cells (PRBCs) and fresh frozen plasma (FFP), while continuing judicious use of crystalloids and colloids.

3. Phase 2: transfusion reaction

(a) When the blood products arrive in the OR, the learner should check it with the circulating nurse.
(b) If the learner fails to check the blood products, the proctor can simulate an acute hemolytic transfusion reaction secondary to ABO incompatibility, with the patient becoming profoundly hypotensive, tachycardic, with hives, and severe bronchospasm with elevated peak pressures and decreased compliance on the ventilator.
(c) If the learner does check the blood, there will still be a transfusion reaction but of less severity, including increased temperature.
(d) The learner should immediately suspect transfusion reaction and should perform the following steps:

(i) Stop the transfusion immediately. The learner may also change out the PIV tubing that contains the triggering blood product.
(ii) Call for help.
(iii) Notify the surgeons and ask them to finish operating as quickly as possible. Depending on the severity of the reaction, they may ask the surgeon to abort and close.
(iv) Provide supportive measures, including:

1. 100% FiO2
2. Administer epinephrine.
3. Evaluate bronchospasm and respiratory distress, including manual bagging to assess compliance and checking of peak pressures. Treat the bronchospasm with albuterol and epinephrine IV.
4. Administer steroids, such as methylprednisolone, hydrocortisone, or dexamethasone.
5. Administer H1-antagonist such as diphenhydramine.
6. Administer H2-antagonist such as ranitidine or famotidine.
7. Support the hemodynamics as indicated with vasopressors and/or inotropes.

(v) Call the Blood Bank and send the remaining blood bag and a sample of the patient's blood to the Blood Bank for testing.

(e) With these interventions, the patient's hemodynamics will stabilize, the bronchospasm and ventilation will improve, and the hives will resolve.

4. Phase 3: disposition planning.

(a) The surgeon will have closed and aborted the case, to return to the operating room another day.
(b) The surgeon will ask the learner whether the patient can be extubated and taken to the Post-Anesthesia Care Unit (PACU) or whether the patient needs to remain intubated and taken to the Intensive Care Unit (ICU).
(c) The learner must weigh the pros and cons of remaining intubated versus attempting extubation.
(d) Questions they should address include:

(i) What is the likelihood of recurrence of the clinical symptoms of transfusion reaction, including hemodynamic instability and bronchospasm?
(ii) Will the patient continue to require ongoing observation and treatment with vasopressors, epinephrine, steroids, and supplemental oxygen?
(iii) What is the likelihood of success at reintubation if the patient due to the upper airway edema from the transfusion reaction and fluid resuscitation?

Scoring Rubric

Table 31.1 Scoring rubric for case scenario on Transfusion Reaction

Topic: Transfusion Reaction			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not completed
Blood loss and transfusion			
Evaluation	Observes the patient becoming increasingly tachycardic and hypotensive. Considers hypovolemic shock as a likely cause of the hemodynamic changes.		
	Communicates the patient's hemodynamic instability to the surgeon.		
Management	Attempts to stabilize the hemodynamics with fluids and vasopressors.		
	Sends appropriate labs, including a complete blood count (CBC) and arterial blood gas (ABG).		
	Identifies anemia on blood gas.		
	Calls for blood products and initiates transfusion in balanced ratio.		

Table 31.1 (continued)

Transfusion reaction			
Evaluation	Checks the blood products with the nurse prior to transfusion.		
	Notices hemodynamic changes and suspects transfusion reaction.		
	Stops transfusion of triggering blood product and discards contaminated IV tubing.		
	Auscultates breath sounds to assess for bronchospasm.		
	Manually bags patient to evaluate compliance.		
Management	Calls for help.		
	Administers fluids and vasopressors to support hemodynamics.		
	Administers 100% FiO2.		
	Administers epinephrine.		
	Administers albuterol.		
	Administers steroids, such as methylprednisolone, hydrocortisone, or dexamethasone.		
	Administers H1-antagonist such as diphenhydramine.		
	Administers H2-antagonist such as ranitidine or famotidine.		
	Calls the Blood Bank and sends them a sample of the transfused blood product and the patient's blood for testing.		
Disposition planning			
	Weighs pros and cons of remaining intubated versus attempting extubation.		
	Discusses plan with the surgeon and/or intensivist.		

Summary of Clinical Teaching Points

What is the difference between a "type and screen" versus a "type and cross" test?

- Cross matching occurs when donor erythrocytes are mixed with the recipients' plasma to check for agglutination.
- Screening will analyze the blood for common antibodies with the risk of a significant hemolytic reaction. The risk of significant hemolytic reaction following screening of a type specific blood is 1:10,000.
- In a type and cross, both the recipient and donor blood cells are ABO-Rh typed. Recipient's blood is mixed with donor's blood and compatibility is established in a three-phase process. In the first phase, ABO errors are detected. In the second phase, the reactants are warmed and additional antibodies such as Rh and partial antibodies are detected. In the final phase, antiglobulin sera is added allowing for the detection of incomplete antibodies such as Kidd, Kelly, and Duffy.

- In a type and screen, the recipient and donor cells are still ABO-Rh typed. However, standard reagents with known ABO-Rh antibodies are added to the recipient's blood. If an antibody is found, the blood bank can give donor negative blood for the identified antibody. While a type a screen does not completely eliminate the risk of all hemodynamically significant transfusion reactions, the risk is reduced to less than 1%.

Explain the relationship between cardiac output and anemia?

- Changes in hemoglobin and hematocrit can be misleading as they depend on plasma volume. Especially in trauma and cases of rapid hemorrhage, hemoglobin values will not accurately reflect the red blood cell (RBC) volume state.
- Anemia will result in a decrease in blood viscosity, and the resulting loss in RBC mass and oxygen transport ability might be partially compensated by increases in cardiac output in healthy patients.
- Transfusion of RBCs can lead to increased RBC volume, increased blood viscosity, and a lower cardiac output. RBC volume can have great variability in its effect on oxygen consumption and delivery.

What factors determine if a patient requires a blood transfusion?

- In deciding whether a patient requires a blood transfusion, one must first determine wheter the patient simply requires volume or increased oxygen carrying capacity.
- Oxygen delivery will be impacted by low hemoglobin; however, this can vary from patient to patient. Classically, impaired tissue oxygen consumption (VO_2) < 100 ml/min/m^2, hemoglobin of <7 gm/dL and an oxygen extraction ratio of greater than 0.5 are indications for blood transfusion.
- Intraoperative and post-operative management of blood loss includes calculating a patient's allowable blood loss, monitoring the amount of intra-operative blood loss, monitoring hemoglobin or hematocrit levels, ensuring adequate perfusion and oxygenation to the vital organs, and providing allogenic or autologous transfusions when required.
- It is assumed that surgical patients requiring intraoperative blood transfusions have similar requirements to critically ill patients in the intensive care unit (ICU) and it is reasonable to transfuse at hemoglobin levels below 7 gm/dL in those without cardiac history. In those with cardiac history, a hemoglobin level of 8 gm/dL is appropriate [1–4].

What are the three major classes of transfusion reactions?

- Transfusion reactions can be divided into three major categories: (1) hemolytic reactions, (2) febrile reactions, and (3) allergic reactions. Secondary or post-transfusion reactions include transfusion related acute lung injury (TRALI), transfusion related acute circulatory overload (TACO), or graft versus host disease (GVHD).

How do patients with acute hemolytic reactions present? What labs and treatment should be performed in patients with a suspected acute hemolytic reaction?

- Acute hemolytic reactions are an antibody reaction to ABO surface antigen on donor red blood cells. These reactions can lead to a severe immune response with hemolysis, complement activation, renal failure, and death. Early signs include fever, tachycardia, hypotension, and chest and lower back pain. Under general anesthesia, many of these symptoms will be difficult to elucidate. However, the combination of hypotension and tachycardia soon after starting a blood transfusion should be cause for alarm. If an acute transfusion reaction is suspected, the provider should stop the transfusion immediately, change any IV tubing with blood product in it, and be prepared to provide supportive care and adequate fluid resuscitation.
- Once the patient has stabilized from an acute hemolytic reaction, the provider should consider sending the blood for a direct Coombs test, obtaining a urinalysis for myoglobin, and sending samples of the patient's blood and the donor blood to the hospital blood bank for detailed analysis.

How do patients with delayed hemolytic reactions present? What labs should be performed in patients with a suspected delayed hemolytic reaction?

- Delayed hemolytic transfusion reactions occur because of incompatibility of minor antigens. This is characterized by extravascular hemolysis with symptoms presenting 2 days to 6 months after a transfusion. Patients may have anemia and jaundice with elevated bilirubin levels. Laboratory studies will show a positive direct antiglobulin test, hyper-bilirubinemia, decreased haptoglobin levels, and hemosiderin in the urine.

How do patients with febrile non-hemolytic reactions present? What labs should be performed in patients with a suspected febrile non-hemolytic reaction?

- Febrile non-hemolytic reactions are less devastating than acute hemolytic reactions but are more common, occurring in up to 1% of all RBC transfusion and 30% of all platelet transfusions. Febrile reactions are a result of antibodies reacting to donor leukocytes.
- Typically, fevers start within 6 h of transfusion and are rarely followed by hypotension or tachycardia. If there is any concern for infection, such as the presence of elevated white blood cell counts, rigors, or dyspnea, then blood cultures should be sent and the patient should be treated for suspected infection. Future febrile reactions can be prevented by pretreating with acetaminophen and hydrocortisone before administering leukocyte-reduced blood.

How do patients with allergic blood transfusion reactions present? What treatments should patients with a suspected allergic transfusion reaction receive?

- Allergic reactions to blood transfusions are the result of sensitivity to donor plasma proteins and can present as a spectrum from mild to severe anaphylaxis, and typically feature a combination of (a) mucocutaneous symptoms, such as

rash, hives, and swelling of the lips; (b) respiratory symptoms, such as bronchospasm, oxygen desaturation, and respiratory distress; (c) gastrointestinal symptoms, such as nausea, vomiting, and diarrhea; and (d) hemodynamic changes, such as hypotension and tachycardia.
- If a provider suspects that a patient is having an allergic reaction, they should immediately stop the transfusion and administer pharmacologic treatment, including an H1-receptor antagonist such as diphenhydramine, an H2-receptor antagonist such as famotidine, steroids such as methylprednisolone or hydrocortisone, a Beta-2-agonist such as albuterol, and epinephrine. The provider should also support hemodynamics as needed with fluid boluses and vasopressors.

What is the pathophysiology, clinical presentation, and treatment of secondary blood transfusion reactions such as transfusion-associated lung injury (TRALI), transfusion-associated circulatory overload (TACO), and graft-versus-host disease (GVHD)?

- TRALI can result from red blood cell, platelet, fresh frozen plasma, or cryoprecipitate transfusion. It involves severe pulmonary insufficiency. Signs of TRALI include fever, dyspnea, new lung infiltrates on chest radiograph, hypotension, and pulmonary edema that develop within 4–6 h of transfusion. TRALI is more likely to occur when anti-HLA antibodies and antileukocyte antibodies present in the donor plasma react with the recipient. Patients suspected of having TRALI require supportive hemodynamic care, and often require advanced ventilation support.
- TACO can present with signs and symptoms of circulatory congestion that are similar to congestive heart failure. These include dyspnea, jugular venous distention, and pulmonary edema. Treatment includes diuretics, advanced ventilation support, and vasopressors to support hemodynamics.
- GVHD is a rate and potentially fatal complication that results from an attack of immunocompetent donor lymphocytes on the immunocompromised host's various tissues. GVHD can present 4–30 days after a transfusion. Initial presentation can include fever and maculopapular rash, as well as anorexia, vomiting, cough, and abdominal pain. Diagnosis can be confirmed through skin biopsy; circulating lymphocytes will have a different HLA phenotype, confirming origin from the recipient. Treatment includes supportive care, but outcomes can be quite poor, so prevention is essential. Irradiating donor blood inactivates donor lymphocytes, making them safer from transfusion into immunocompromised recipients [4, 5].

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Chapter 32
Pulmonary Hypertension (Adult)

Suraj Trivedi, Matt Mueller, and Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Understand the intraoperative anesthetic management of pulmonary hypertension.
2. Review the types of hemodynamic monitoring required to manage pulmonary hypertension.

Simulator Environment

1. Location: operating room of an adult hospital.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: 2 × large bore peripheral intravenous (PIV) catheters.
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide ($ETCO_2$).
   (d) Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, dopamine, phenylephrine, ephedrine, albumin, lactated ringers, vasopressin, epinephrine, nitroglycerin, norepinephrine.

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(e) Equipment available:

(i) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), and suction.
(ii) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
(iii) Crash cart with defibrillator.

Actors

1. Surgeon
2. Circulating nurse
3. Scrub tech

Scenario Development

1. Background

(a) You are the anesthesiologist starting an emergent open reduction and internal fixation of a humerus fracture on a 71-year-old man who was just in a motor vehicle collision.
(b) On arrival to the emergency department, the patient was conscious. Past medical history is notable for prior myocardial infarction 5 years ago, type 2 diabetes mellitus, and pulmonary hypertension.
(c) The patient reports increasing shortness of breath over the last several months with activity.
(d) The scenario begins in the operating room. Induction of general anesthesia has begun. The intubation attempt was prolonged as the junior anesthesiology resident struggled to obtain an adequate view. The patient was intubated without difficulty and listed as a grade 2b view.

2. Phase 1: hypotension from hypercarbia, acidosis, and pulmonary hypertension exacerbation.

(a) While the surgeons are undressing the patient and scrubbing, the learner will note that the patient is persistently hypotensive.
(b) The learner should simultaneously diagnose and treat by performing the following:

(i) Review monitors, including EKG, NIBP cuff, temperature, ETCO2.
(ii) Review ventilator settings.
(iii) Review recent medication administration.

(c) The learner should note that the patient is hypotensive, tachycardic, and the ETCO2 is elevated in the 70s.

(d) The learner should suspect hypercarbia, acidosis as an exacerbator of underlying pulmonary hypertension.
(e) The learner should take steps to decrease the hypercarbia and improve the acidosis by increasing the minute ventilation

(i) Increase the respiratory rate and/or tidal volume.
(ii) Hyperventilate with 100% fraction of inspired oxygen (FiO_2).

(f) The learner should also support hemodynamics and initiate more invasive hemodynamic monitoring prior to the start of surgery:

(i) Initiate inotropic support to support the right heart and prevent acute right heart failure. This may include dopamine, dobutamine, milrinone, norepinephrine, vasopressin, etc.
(ii) Administer vasopressors to augment the mean arterial pressure and promote end-organ perfusion.
(iii) Place an arterial line and send an arterial blood gas (ABG) to evaluate for anemia, acidosis, and electrolyte derangements.

1. The arterial line will show a systolic blood pressure in the 60s–70s.

(iv) Consider placing a central venous catheter with a pulmonary artery catheter.

1. If the learner does place a pulmonary artery catheter, they will observe an elevated pulmonary artery pressure with a mean of >80 mmHg.

(v) Consider placing a trans-esophageal echocardiogram (TEE).

1. On TEE imaging, the learner will notice a dilated right atrium, dilated right ventricle, tricuspid regurgitation, and poor right ventricle contractility.

(vi) Consider starting medications that will directly vasodilate the pulmonary vasculature, such as inhaled nitric oxide (iNO) or intravenous epoprostenol.

(g) With initiation of these interventions, the patient's hemodynamics will improve.

3. Phase 2: hypotension with repositioning.

(a) The surgeons have begun to reposition the patient from a supine position into a beach chair position when the patient suddenly becomes hypotensive.
(b) The learner should alert the surgeons and ask them to return the patient to a supine position.
(c) The learner should identify the acute drop in preload as a cause of decreased cardiac output and decreased perfusion to the heart.
(d) The learner should augment the preload by administering crystalloids and/or colloids.
(e) The surgeons will ask if they can proceed with the case. The learner can attempt to reposition the patient more slowly from supine to beach chair to minimize the rate of drop in preload.

Scoring Rubric

Table 32.1 Scoring rubric for case scenario on Pulmonary Hypertension

Topic: Pulmonary Hypertension			
Participant Name:			
Evaluator Name:			
Score:			
		Completed	Not completed
Hypercarbia after induction			
Evaluation	Notes the patient becoming increasingly tachycardic, hypotensive, and hypercarbic after intubation.		
	Communicates the patient's hemodynamic instability to the surgeon.		
	Reviews monitors, ventilator settings, and recent medication administration.		
	Suspects hypercarbia and respiratory acidosis as acute exacerbators of underlying pulmonary hypertension.		
Management	Increases minute ventilation by increasing respiratory rate and/or tidal volume.		
	Hyperventilates with 100% fraction of inspired oxygen (FiO_2).		
	Supports hemodynamics with vasopressors and inotropes.		
	Places an arterial line.		
	Sends an arterial blood gas.		
	May place a central venous catheter with a pulmonary artery catheter.		
	Recognizes an elevated pulmonary artery pressure.		
	Inserts a trans-esophageal echocardiogram probe.		
	Correctly identifies and interprets TEE findings as consistent with right heart strain.		
	Considers administering medications that are direct vasodilators of the pulmonary vasculature such as inhaled nitric oxide (iNO) or intravenous epoprostenol.		
Decreased preload from positioning			
Evaluation	Identifies positioning change as cause of decreased preload.		
Management	Alerts and surgeon and asks to reposition patient from beach chair to supine.		
	Administers a fluid bolus with crystalloids or colloids.		
	Regarding case continuation, considers repositioning slowly after preload augmentation.		

Summary of Clinical Teaching Points

What is Pulmonary hypertension?

- Pulmonary hypertension (PH) is a group of disorders defined by the presence of mean pulmonary artery pressure (mPAP) >20 mmHg according to the World Symposium on Pulmonary Hypertension (WSPH).
- PH is classified into five groups dependent upon the etiology.
- Treatment varies depending on group and phenotype.
- PH is associated with a high rate of morbidity and mortality.

How is pulmonary hypertension classified? [1, 2]

- Group 1: pulmonary arterial hypertension (PAH)
- Group 2: PH due to left heart disease
- Group 3: PH due to lung disease and/or hypoxia
- Group 4: PH due to pulmonary artery obstruction
- Group 5: PH with unclear and/or multifactorial etiology

What are some perioperative considerations in patients with pulmonary hypertension? [3]

- Hypercarbia, acidosis, and hypoxemia increase pulmonary vascular resistance (PVR), and should be avoided.
- Patients with PH are sensitive to changes in preload. Central venous pressure (CVP) may be used as a surrogate for preload and should be maintained at 6–10 mmHg.
- Exacerbations of pulmonary hypertension may lead to acute right ventricular (RV) failure in severe cases, and efforts should be made to minimize RV oxygen demand by reducing afterload and avoiding tachycardia.
- Alternatives to general anesthesia (e.g., local anesthesia) should be considered when clinically appropriate as patients with PH are sensitive to sudden hemodynamic changes.
- High thoracic spinal or epidural anesthesia may result in an acute drop in systemic vascular resistance (SVR) and heart rate, which may lead to an increase in preload and a decrease in cardiac output, thus negatively impacting RV function.

What perioperative monitoring should be used for patients with pulmonary hypertension? [4, 5]

- All patients should have standard non-invasive monitoring with electrocardiography, pulse oximetry, non-invasive blood pressure, and end-tidal capnography.
- Unless a minor procedure, patients with significant PH should have intra-arterial blood pressure monitoring throughout the operative course.
- Central venous catheters facilitate continual central venous pressure monitoring and should be used in patients with severe PH. Central venous catheters are also preferred for administering vasopressors and inotropic medications.

- Pulmonary artery catheters may be used for early identification of exacerbations of PH. However, there is paucity of outcome data to support their use.
- Transesophageal echocardiogram may be used to rapidly detect acute intraoperative changes.

Explain the principals of anesthetic induction and maintenance in patients with pulmonary hypertension? [5–7]

- Induction of anesthesia
  - Ensure a hemodynamically stable induction with the use of short acting sedatives (e.g., etomidate) and opioid analgesia (e.g., fentanyl) to blunt the sympathetic response during airway manipulation.
- Maintenance of anesthesia
  - Hemodynamic stability should be maintained regardless of the anesthetic used.
  - Nitrous oxide may increase pulmonary vascular resistance and should be avoided.
  - Ketamine may increase PVR and cardiac output, which may be deleterious in the patient with PH, use with caution.

What ventilator settings should be used for patients with pulmonary hypertension?

- Hypercarbia, acidosis, and hypoxemia should be avoided to limit increases in PVR.
- Initial tidal volumes should be set to 6–8 mL/kg, but larger tidal volumes may be needed in patients with severe PH who cannot tolerate high amounts of positive end-expiratory pressure (PEEP).
- As with all patients, the appropriate amount of PEEP is patient specific. A PEEP strategy should be employed to limit alveolar collapse while also limiting alveolar overdistension. However, higher levels of PEEP will increase PVR and reduce venous return, and should be used with caution in patients with PH. PEEP should be initially set to 5 cmH_20 and titrated for adequate oxygenation.

What are some targeted medical therapies for patients with PH [6, 7]

- Therapies to reduce pulmonary vascular resistance such as epoprostenol, iloprost, treprostinil, and inhaled nitric oxide may be suitable for patients with group 1 PH (PAH), but may be detrimental to patients non-group 1 PH. In patients with left ventricular (LV)x` failure, the LV may not be able to accommodate the increased LV preload that occurs with pulmonary arterial dilatation.
- Patients who are on maintained on chronic outpatient therapy, these therapies should be continued intraoperatively.
- Inhaled nitric oxide or inhaled epoprostenol may be administered intraoperatively to treat acute intraoperative increases in PVR.
- In some cases, milrinone may be a suitable rescue therapy for acute increases in PVR when pulmonary vasodilation and inotropy are, both, needed.

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Chapter 33
Awareness Under Anesthesia (Adult)

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Case Outline

Learning Objectives

1. Describe the preoperative assessment of a trauma patient.
2. Review the risk factors for awareness under anesthesia.
3. Discuss considerations for induction of anesthesia in a trauma patient.
4. Review challenges and considerations when vascular access is compromised or lost during induction of general anesthesia.
5. Discuss the postoperative management of awareness under anesthesia.

Simulator Environment

1. Location: operating room of a large tertiary care center that cares for traumas.
2. Manikin setup:
   (a) Age: young adult, obese
   (b) Lines: 1 × 20 Gauge (G) peripheral intravenous (PIV) line in the forearm.
   (c) Monitors: non-invasive blood pressure (NIBP) cuff, 5-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide ($ETCO_2$).
   (d) Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, midazolam, dopamine, phen-

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ylephrine, ephedrine, albumin, lactated ringers, vasopressin, epinephrine, nitroglycerin, norepinephrine.

(e) Equipment available:

(i) Airway equipment: ventilator, face mask, laryngoscope and cuffed endotracheal tubes (ETTs) of various sizes, stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), and suction.
(ii) Vascular access equipment: ultrasound, tourniquet, various sized PIV catheters, arterial line, fluid warmer.
(iii) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG.
(iv) Code or Crash cart with defibrillator.

Actors

1. Surgeon
   (a) The surgeon is in the operating room and is eagerly waiting for the patient to be intubated so they can start the surgery.
2. Circulating nurse
   (a) The circulating nurse can be helpful but is currently busy opening equipment for the scrub technician.
3. Scrub technician
   (a) The scrub technician is busy opening equipment trays.

Scenario Development

1. Background
   (a) You are the anesthesiologist on call at a level 1 trauma center. You are in the operating room preparing to start a level 1 open reduction internal fixation of an open tibia fracture. The patient is a 32-year-old man, 142 kg, BMI 43, who was in a motor vehicle accident.
   (b) Pre-operative history: morbidly obese, last ate 2 hours ago, anxiety on paroxetine, chronic lower back pain, takes oxycodone 15 mg per oral three times daily. Drinks a bottle of wine daily.
   (c) Pre-operative labs: hemoglobin 12.0 g/dL, platelets 220,000/mcL, potassium 4.0 mol/L, creatinine 0.8 mg/dL. Normal liver function tests.
   (d) Pre-operative imaging: chest x-ray and computer tomography scans did not show any additional injuries besides the open tibial fracture.
2. Phase 1: pre-operative evaluation and informed consent.
   (a) Physical exam shows an obese man who is grimacing in pain. There is no evidence of head or neck trauma.

(b) The patient currently has one 20 G PIV) in the left arm.
(c) Pre-operative vital signs: blood pressure 110/65, heart rate 87, oxygen saturation 100% on room air.
(d) The learner will discuss the risks of anesthesia with the patient, including a discussion of the potential for awareness under anesthesia, given the patient is a level 1 trauma with substance use. The learner should emphasize that although he is at risk for awareness under anesthesia, precautions will be taken to minimize this risk.

3. Phase 2: PIV) infiltration during induction of anesthesia.

(a) Preparation for induction of anesthesia:

(i) The learner should identify that this patient is considered to have a full-stomach, so he requires a rapid sequence induction.
(ii) The patient is covered in blankets during IV induction, including his PIV site.
(iii) The learner should optimize the sniffing position, pre-oxygenate for at least 3–5 minutes, and determine whether to apply cricoid pressure. The learner may discuss the pros and cons of cricoid pressure.
(iv) The learner should ensure that the PIV site is visible during induction.

(b) Induction of anesthesia:

(i) The learner will administer their IV induction medications.
(ii) The patient will close their eyes and appear to lose consciousness.

1. If succinylcholine was administered, there will be no fasciculations after an expected amount of time.

(iii) If the learner inspects the PIV site, they will notice that the PIV site has infiltrated.

1. If the learner thinks the patient has achieved an appropriate plane of anesthesia and muscle relaxation, then they may choose to attempt intubation.

(a) If they attempt intubation, the patient will cough and buck with laryngoscopy and develop tachycardia and hypertension.
(b) The learner should remove the laryngoscope and re-evaluate their options for re-establishing vascular access and administering induction agents and muscle relaxants, including the following:

(i) Ask an assistant to quickly place a new PIV.
(ii) Administer intramuscular medication such as ketamine 2–4 mg/kg.
(iii) If PIV access is difficult, they may ask an assistant to place an intraosseous line.
(iv) While performing these steps, the learner should resume mask ventilation to restore adequate oxygenation and ventilation.

2. If the learner thinks the patient is not an appropriate depth of anesthesia or muscle relaxation, then they may pursue any of the following options to achieve this:

   (a) Ask an assistant to quickly place a new PIV).
   (b) Administer intramuscular medication such as ketamine 2–4 mg/kg.
   (c) If PIV access is difficult, they may ask an assistant to place an intraosseous line.
   (d) While performing these steps, the learner should resume mask ventilation to restore adequate oxygenation and ventilation.

(iv) If the learner does not inspect the PIV) site and presumes the patient is at an adequate depth of anesthesia and muscle relaxation, they will likely attempt intubation. When they do attempt intubation, the patient will cough and buck with laryngoscopy and develop tachycardia and hypertension.

1. The learner should remove the laryngoscope and re-evaluate their options for re-establishing vascular access and administering induction agents and muscle relaxants, including the following:

   (a) Ask an assistant to quickly place a new PIV.
   (b) Administer intramuscular medication such as ketamine 2–4 mg/kg.
   (c) If PIV access is difficult, they may ask an assistant to place an intraosseous line.
   (d) While performing these steps, the learner should resume mask ventilation to restore adequate oxygenation and ventilation.

(v) The learner will be able to re-establish vascular access, administer induction agents and muscle relaxants, and proceed with the remainder of the case uneventfully.

4. Phase 3: post-operative evaluation for awareness under anesthesia.

(a) The patient will have been in the post-anesthesia care unit (PACU) for an hour. The PACU nurse will call the learner to bedside to evaluate the patient for awareness under anesthesia. The PACU nurse will report that the patient has been anxious and tearful about their experience under anesthesia. The patient will also report that their arm at the site of the PIV infiltration is swollen and tender.

(b) The learner should perform a detailed assessment, including a history with questions specific to awareness under anesthesia, and a physical exam evaluating the extremity with the PIV infiltration.

(i) Questions regarding awareness under anesthesia should include:

1. What is the last thing the patient remembers before going to sleep?
2. What is the first thing the patient remembers upon waking up?

3. What does the patient remember, if anything, between going to sleep and waking up?

(ii) PIV infiltration examination should include:

1. Palpation of pulses.
2. Assessment of color.
3. Assessment of swelling or edema.
4. Assessment of pain.
5. Assessment of numbness or tingling.
6. Assessment of motor function.

(c) The learner should recognize intraoperative awareness and offer the following:

(i) Acknowledge the patient's concerns.
(ii) Inform them of the details of the intraoperative events that may have led to the intraoperative awareness.
(iii) Offer psychological counseling services.
(iv) Consider contacting the hospital's risk management and patient liaison services.

Scoring Rubric

Table 33.1 Scoring rubric for case scenario on Awareness Under Anesthesia

Topic: Awareness Under Anesthesia		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not completed
Pre-operative assessment		
Completes a history and physical exam.		
Evaluates current IV access.		
Discusses approach to general anesthesia.		
Discusses risk of awareness under anesthesia.		
Induction		
Optimizes sniffing position and perform good pre-oxygenation.		
Prepares for rapid sequence induction.		
May administer cricoid pressure. When queried, appropriately discusses pros and cons of cricoid pressure.		
Ensures the IV is visible during induction		
Identifies infiltrated PIV.		
Pursues an alternate way to achieve an adequate depth of anesthesia		

(continued)

Table 33.1 (continued)

Post-operative evaluation		
Evaluates the patient post-operatively in PACU.		
Asks questions to assess for possible awareness under anesthesia.		
Discusses what happened with the patient and provides details about intraoperative events.		
Discusses options for emotional support. May solicit help of patient liaison or risk management services.		

Summary of Clinical Teaching Points

Intraoperative awareness can lead to prolonged psychological sequelae such as post-traumatic stress disorder and depression. The incidence of explicit intraoperative recall has been reported to be as frequent as 1 in every 1000 patients who receive general anesthesia [1].What patient populations or conditions are associated with an increased risk of awareness under anesthesia? [2–4]

- Traumas
- Obstetrics
- History of awareness under anesthesia
- Total intravenous anesthetics (TIVA)
- Use of neuromuscular blocking drugs, especially non-depolarizing agents
- Cardiac surgery
- Patient history of substance use disorder
- Anesthesia equipment malfunction (example: vascular access, ventilator, vaporizer)

What routes, other than intravenous, are available to administer medications for induction of anesthesia?

- Intraosseous (IO) [5]
  - Intraosseous kits are usually not readily available in operating rooms.
  - Inserting an intraosseous line is typically simple and quick to do from a technical standpoint.

    Obesity increases the level of difficulty because the bony landmarks that guide intraosseous placement can be more challenging to palpate and there is greater depth of subcutaneous tissue to traverse.

  - Common insertion sites include: tibial tuberosity, humeral head, and sternum.
  - The onset of action for medications given intraosseous versus intravenous is usually comparable.

- Intramuscular (IM)
  - A limited number of induction medications can be given intramuscular, and include ketamine and succinylcholine.
  - Ketamine

    At doses of 4–6 mg/kg IM, a dissociative state will be achieved within 4 minutes.
    At doses of 6–14 mg/kg IM, surgical anesthesia can be achieved for approximately 15–30 minutes.

  - Succinylcholine

    Dose is 4 mg/kg IM, with a maximum of 150 mg.
    Time to onset of action is 4–6 minutes.
    Clinical effects can be seen after 2 minutes in adults.

- Inhalational induction
  - This is more commonly done in pediatric anesthesia. It can be done in adult patients but is challenging to do, largely due to upper airway obstruction and difficulty maintaining a good seal with the face mask and ensuring adequate ventilation.
  - The most commonly used inhalational agents are nitrous oxide and sevoflurane.
  - Even with an inhalational induction, without the administration of muscle relaxant, the patient will have suboptimal intubating conditions and is at high risk of laryngospasm with attempted intubation.
  - This can be done to achieve a deeper plane of anesthesia until intravascular or intraosseous access can be obtained.

Is cricoid pressure a required component for a rapid sequence induction?

- Full stomach precautions and rapid sequence induction are an indication for cricoid pressure. However, cricoid pressure is of controversial utility.
- Challenges to cricoid pressure [6]:
  - Cricoid pressure is often done with inadequate force and inappropriately applied to effectively compress the esophagus with the cricoid ring.
  - Cricoid pressure can actually provide suboptimal intubating conditions and impede the anesthesiologist's ability to obtain an adequate view of the glottic opening for intubation.
  - Cricoid pressure can cause a patient to vomit when applied as the patient is undergoing induction of anesthesia.
  - In the event of a difficult airway where the anesthesiologist needs to perform bag mask ventilation, cricoid pressure can impede effective ventilation.

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Chapter 34
Seizure During an Awake Craniotomy (Adult)

Merrick Tan and Minh Tran

Case Outline

Learning Objectives

1. Discuss the anesthetic considerations for awake craniotomies.
2. Develop a strategy for intraoperative management of seizures during an awake craniotomy.
3. Review how to appropriately resuscitate a patient who is post-ictal and unable to protect their airway.

Simulator Environment

1. Location: operating room of an adult hospital
2. Manikin setup:
   (a) Age: adult
   (b) Lines: two peripheral intravenous line (PIV) lines, radial arterial line, foley catheter.
   (c) Monitors: non-invasive blood pressure cuff, 5-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide (ETCO2).

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3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, fentanyl, midazolam.
4. Equipment available
   (a) Airway equipment: ventilator, nasal cannulae with ET CO2 connection, face mask, laryngoscope and endotracheal tube (ETT), stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG
   (c) Lines: PIV, arterial line kit
   (d) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is assisting surgeon with instruments.
2. Circulator nurse
   (a) The nurse is available in the OR.
3. Surgeon
   (a) The surgeons are focused on examining the patient's sensory and motor exam.

Scenario Development

1. Background
   (a) You are the anesthesiologist performing an awake craniotomy for Deep Brain Stimulator (DBS) implantation. The patient is an otherwise healthy 72-year-old woman with medication refractory Parkinson's Disease. The initial pinning, positioning in slight reverse Trendelenburg, and exposure craniotomy are performed uneventfully under monitored anesthetic care after a scalp block and using propofol and remifentanil infusions. Next, the surgeons pass microelectrodes targeting areas of the brain responsible for tremors where they will deposit the DBS leads. The surgical team then requests to wake up the patient in order to obtain a sensorimotor exam.
2. Phase 1: intraoperative seizure management
   (a) The learner should be able to first understand the potential complications and anesthetic considerations of awake craniotomies such as bleeding, nausea/vomiting, respiratory depression, venous air embolism and seizures.

(b) The learner should identify the hemodynamic and exam changes that can manifest with seizures. The learner should recognize that neurologic exam changes may be masked by the effects of anesthesia.
(c) When the diagnosis of seizure is made, the learner should recognize this situation as an intraoperative emergency and take the appropriate steps, including:

(i) Notifying the surgical team and considering calling for help.
(ii) Managing the seizure with the pharmacological agents that are immediately available in the operating room, such as midazolam or another fast-acting benzodiazepine, and/or propofol.
(iii) Determining if there are any reversible causes of the seizure and removing any provoking stimuli. Example: in this scenario, the microelectrodes.
(iv) Ensuring adequate oxygenation and ventilation. This may require applying positive-pressure ventilation through mask ventilation or a supraglottic airway device.
(v) Supporting hemodynamics.

3. Phase 2: resuscitation following a seizure when protective airway reflexes are compromised.

(a) After the seizure stops and the patient is hemodynamically stable, all parties will agree to continue with the case.
(b) The anesthesiologist should load the patient with an anti-epileptic for secondary prophylaxis.
(c) Moments later, the patient's pulse oximeter reading will steadily decline. Upon survey of the patient's face, the learner will notice vomit coming from the patient's mouth and nose.
(d) The learner should recognize the vomiting as an intraoperative emergency with the potential for aspiration. The learner should notify the surgical team of the change.
(e) If the learner does not decide to immediately intubate:

(i) At the very least, they should consider suctioning the airway, turning up the oxygen flow rate, and immediately placing the patient in the Trendelenburg position.
(ii) Despite these supportive measures, the patient's oxygen saturation will remain in the high 80s-low 90s.
(iii) The patient will vomit again.

(f) If the learner does decide to intubate:

(i) They should request to the surgeons that the patient be removed from the Mayfield pins and a flat head rest be placed in preparation for intubation.

(ii) Once the airway is secure, oxygen saturation will improve.

(iii) If desaturation occurs rapidly before unpinning can be accomplished, the learner should follow the American Society of Anesthesiologists' Difficult Airway Algorithm, with consideration of placing a rescue supraglottic airway device to improve oxygenation and ventilation.

Scoring Rubric

Table 34.1 Scoring rubric for case scenario on Seizure during Awake Craniotomy

Topic: Seizure During an Awake Craniotomy (Adult)		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not completed
Seizure recognition and management		
Recognizes vital sign changes and/or neurologic exam changes.		
Promptly verbalizes concern for intra-operative seizure to the surgical team.		
Asks the operating room nurse to call for help.		
Increases supplemental oxygen delivery (urgency likely dependent on exam changes, i.e., concern for airway protection, decrease in O2 saturation).		
Promptly treats the seizure with an intravenous agent such as propofol and/or midazolam.		
Simultaneously assesses oxygenation/ventilation and circulation.		
Investigates any reversible causes of seizure and identifies the microelectrodes as a likely culprit.		
Asks for the removal of the microelectrodes as soon as safely feasible.		
Post-ictal airway compromise and resuscitation		
Identifies change in vitals and decreasing oxygen saturation.		
Notifies surgical team of the change.		
Calls for help.		
Requests that the patient be repositioned to supine with the head neutral, in preparation for advanced airway management.		
Suctions out the airway for any residual gastric contents.		
Increases supplemental oxygen delivery and moves to advanced airway, such as face mask with Mapleson or ventilator circuit. Provides positive pressure ventilation.		
Supports hemodynamics with inotropes and/or pressors to maintain adequate perfusion pressures.		
Proceeds with timely intubation when oxygen saturation does not improve.		
If desaturation occurs before unpinning and bag mask ventilation is not feasible given the upright position of the patient, learner will follow the American Society of Anesthesiologists' Difficult Airway Algorithm.		

Summary of Clinical Teaching Points

Why would a neurosurgeon perform an awake craniotomy? [1–3]

- The goal of an awake craniotomy is to operate on an area of the brain with as little damage to the surrounding brain parenchyma as possible. This approach helps minimize the amount of postoperative neurologic dysfunction.
- Despite careful surgical technique, it can be challenging to specifically locate the brain tissue of interest. There are imaging modalities such as intraoperative magnetic resonance imaging, ultrasound and neuronavigation that can help identify lesions. However, the gold standard for testing neurologic function is having an awake and cooperative patient.

What do you need to know pre-operatively? [1, 3]

- As with any anesthetic, it is important to inquire about a patient's medical history, surgical history, medications, allergies, and remarkable lab values to understand how these factors may interplay with the anesthetic plan.
- Any available imaging such as computed tomography (CT) or magnetic resonance imaging (MRI) scans should be reviewed to appreciate the underlying area of brain function that may be compromised.
  - If the patient has a known history of seizures, clarify how their seizures typically present, which anti-epileptics they are currently taking and the timing of their last dose, as well as any anti-epileptics that they have tried in the past and their response.
- In order to recognize any intraoperative neurologic changes as a result of surgery, anesthesia, or both, it is critical to perform an extensive baseline neurologic exam prior to starting the case.
- It is imperative that the anesthesiologist counsel the patient on the exact steps of the procedure and ensure patient co-operation from the start. Patients who are skeptical, anxious, severely claustrophobic or unwilling to cooperate do not make good candidates for an awake craniotomy.
- Lastly, patients should be counseled on the specific risks, benefits, and alternatives of the operation, as would be done for any other case.

What are the anesthetic considerations for a patient undergoing an awake craniotomy? [3, 4]

- Patients undergoing an awake craniotomy can be monitored in accordance with guidelines provided by the American Society of Anesthesiologists. Routine monitors include pulse oximetry, electrocardiogram, non-invasive blood pressure, capnography, and temperature. Invasive monitoring is generally not required, unless indicated by the patient's medical history, such as extensive cardiopulmonary disease.
- Major complications that can occur with awake craniotomies include bleeding, venous air embolism (VAE), seizure, airway compromise such as upper airway

obstruction, and a sudden inability to cooperate with the procedure that then requires emergent conversion to general anesthesia or abortion of the surgery.

- Appropriate patient selection is critical in in the preoperative period as patient positioning will make airway management even more challenging in emergency situations. For these surgeries, the patient will be positioned with the head of the table rotated 180 degrees away from the anesthesiologist; with the patient's head in Mayfield pins; and the patient positioned potentially semi-sitting or lateral. This is suboptimal should the patient become uncooperative or develop airway complications because it will be challenging for the anesthesiologist to get to the head of the bed.

How would you manage an intra-operative seizure? [5]

- Seizures can be caused by either the patient's underlying pathology or by direct cortical stimulation during the procedure.
- Symptoms of a seizure include the following: (1) the patient stops responding to questions; (2) the patient has a sudden loss of consciousness; (3) the patient has fluttering eyelids; (4) the patient may display gestures classic of a tonic-clonic episode such as repetitive/rhythmic movements. For a craniotomy done under general anesthesia, as opposed to an awake craniotomy done under monitored anesthesia car and sedation, electroencephalographic (EEG) signals may help identify seizure onset. This is especially helpful if a neuromuscular blocking agent had previously been administered.
- With the brain exposed, seizures may be responsive to simple cold irrigation over the cortex. If the seizure is persistent, small boluses of propofol or an intravenous fast-acting benzodiazepine such as midazolam or lorazepam can be administered.
- During neurosurgical procedures, patient positioning is often suboptimal for airway management. It is prudent for the anesthesiologist to always have backup airway equipment and planning in place should the airway become emergently compromised. This may include having a laryngoscope, styletted endotracheal tube, rescue airway equipment with induction medications readily available during awake craniotomies. A "pre-procedural timeout" can also be done prior to incision in which contingency plans are discussed to reposition the patient in suitable intubating conditions. This may involve leveling the operating room bed, removing the patient from head pins, and replacing the headboard.

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Chapter 35
Out of Operating Room Considerations and Neurointerventional Radiology (Adult)

Merrick Tan and Minh Tran

Case Outline

Learning Objectives

1. Discuss the perioperative management of patients undergoing emergent intracranial revascularization therapy.
2. Review the preparation and considerations for administering an anesthetic outside of the traditional operating room suite.

Simulator Environment

1. Location: interventional radiology suite.
2. Manikin setup:
   (a) Age: adult
   (b) Lines: one peripheral intravenous (PIV) line.
   (c) Monitors: non-invasive blood pressure cuff, 5-lead electrocardiogram (EKG), pulse oximeter, end-tidal carbon dioxide ($ETCO_2$).

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3. Medications available: normal saline, propofol, etomidate, succinylcholine, rocuronium, epinephrine, phenylephrine, ephedrine, fentanyl, midazolam, nicardipine.
4. Equipment available
   (a) Airway equipment: face mask, nasal cannula, ventilator, face mask, laryngoscope and endotracheal tubes (ETT), stylet, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction.
   (b) Monitors: pulse oximeter, blood pressure cuff, 5-lead EKG, $ETCO_2$.
   (c) Lines: arterial line kit, central line kit, PIV kits
   (d) Paperwork: pre-operative anesthesia history and physical

Actors

1. Scrub tech
   (a) The scrub tech is opening sterile trays.
2. Circulator nurse
   (a) The nurse is busy getting report from the floor nurse who has been caring for the patient.
3. Surgeon
   (a) The surgeon has just arrived and is in the locker room changing into scrubs.

Scenario Development

1. Background
   (a) You are the anesthesiologist on call at a tertiary care center. You receive the following page: "74-year-old female for emergent revascularization with neuroIR."
   (b) Upon arrival to the interventional radiology (IR) suite, you learn that the patient presented to the emergency department 1 h ago for altered mental status. On review of systems, she has also had worsening dyspnea on exertion and lower extremity swelling for the past 3 months.
   (c) Notable past medical history includes coronary artery disease (CAD) status post coronary artery bypass graft (CABG) and insulin dependent type 2 diabetes mellitus. Most recent transthoracic echocardiogram (ECHO) was 10 years ago and showed reduced left ventricular systolic function with an ejec-

tion fraction of 30%. She also had a prior hemorrhagic stroke many years ago due to "blood pressure" issues and was taken off all anticoagulants.

(d) Vitals on the transport monitor show the following: heart rate 120 beats per minute, blood pressure 192/102, respiratory rate 18 breaths per minute, oxygen saturation 89%.

(e) Physical exam is notable for complete right-sided hemiplegia with garbled speech and agitation that is difficult to control. This is a change from earlier in the morning according to her daughter. The patient is only oriented to self. The nurse also informs you that the patient was a difficult vascular access and the 22 gauge PIV in their antecubital is very "positional."

(f) The anesthesia technician on-call arrives and asks you what you will need to start the case.

2. Phase 1: equipment setup for a case outside of the main operating room.

(a) The learner arrives to the IR Suite and is approached by the anesthesia technician asking what additional equipment the provider would like for the case. There is an anesthesia ventilator and basic monitors present. No other equipment is readily available.

(b) The learner should go through a checklist to ensure that they have all the required equipment to run an anesthetic. Example mnemonic includes "MOMSAID," which stands for (M)achine, (O)xygen, (M)onitor, (S)uction, (A)irway, (I)ntravenous access, (D)rugs.

(i) Ensure that the anesthesia machine is turned on and tested for any leaks.

(ii) Locate the backup oxygen tank and verify that it is not empty.

(iii) Check for a backup hand ventilatory system, such as a Mapleson circuit or an Ambu Bag.

(iv) Check for a functioning monitor and associated cables, as well as any additional desired monitors. Standard American Society of Anesthesiologist (ASA) monitors include electrocardiogram, pulse oximetry, non-invasive blood pressure cuff, end-tidal capnogram, and temperature. Additional desired monitors may include arterial line, central venous pressure, or pulmonary artery pressure monitoring. This particular patient would warrant an arterial line transducer given the patient's significant cardiac history and the hemodynamic control required for an intracranial revascularization.

(v) Ensure suction is working.

(vi) Prepare an airway setup including an endotracheal tube and laryngoscope of appropriate sizing for the patient.

(vii) Set up an extra kit to start a peripheral intravenous (PIV) line. Prime IV tubing for a fluid line with crystalloid solution.

(viii) Verify medications necessary for the case, including induction agents, pressors, and emergency drugs.

3. Phase 2: Anesthetic planning for an emergent intracerebral revascularization

   (a) Prior to the arrival of the attending interventionalist, the surgical intern admits this is their first revascularization and asks what type of anesthetic is typically administered for this type of case.
   (b) The learner should discuss with the intern the possible anesthetic possibilities including general anesthetic (GA) versus monitor anesthetic care (MAC).
   (c) Shortly after, the attending surgeon walks in and requests that the patient not undergo general anesthesia so that they can obtain a neurologic exam immediately during and after the case. They confirm that the patient has not eaten for >24 h.
   (d) The learner should then be prompted to discuss their anesthetic plan, including:

      (i) Type of anesthetic: general should be chosen for this case given her neurological status which would make sedation difficult to achieve. Also given her cardiac status she may find it difficult to remain flat for the procedure under sedation.
      (ii) Monitors, including pre-induction arterial line.
      (iii) Placement of an additional PIV (the existing 22 G PIV will not be sufficient) and an arterial line for close hemodynamic monitoring.
      (iv) Induction plan.
      (v) Maintenance plan.
      (vi) Emergence and extubation plan.

   (e) The surgeon requests that the case not be delayed for an arterial line and questions the placement of an additional PIV, considering the patient came from the floor with a PIV.

      (i) At this point, the learner should communicate the patient's risk factors and considerations for this particular procedure that warrant a preoperative arterial line and the placement of more robust intravenous access.
      (ii) The learner should also confirm their understanding of the importance of having the revascularization proceed as quickly as possible to minimize delay to cerebral revascularization.
      (iii) If there is difficulty placing the arterial line, advanced learners would discuss with the interventionalist obtaining an awake femoral arterial access before induction of a general anesthetic.

   (f) The case gets underway and that concludes the simulation exercise.

Scoring Rubric

Table 35.1 Scoring rubric for case scenario on Out of Operating Room Considerations and Neurorevascularization

Topic: Out of Operating Room Considerations and Neurorevascularization (Adult)		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not completed
Planning for a case outside of the main operating room		
Performs an adequate check of the necessary equipment, ensuring it is available and functioning: Anesthesia machine. Backup oxygen tank AND hand resuscitator bag. Monitors (including arterial line transducer). Suction. Airway setup (including a backup emergency airway). Secures more robust intravenous access for the case. Intubation drugs, drugs to quickly treat hemodynamic changes during the case, and emergency/code dose drugs are available.		
Ensures adequate space for access to the patient, ventilator, and support equipment.		
Recognizes who is in the room and anticipates how to call for help in an unfamiliar environment.		
Planning for a case in the interventional radiology suite/emergent cerebral revascularization		
At a minimum, obtains detailed history inclusive of: History of present illness (neurologic changes from baseline, anticoagulation status ± last dose). Pertinent medical history (focused neurologic, cardiac, and pulmonary review of systems). Prior anesthetics ± complications. Medications. Allergies. Nil per os (NPO) status.		
Performs a focused neurologic, cardiac, and pulmonary exam. Baseline Glascow coma scale, focal neurological deficits and pupillary size should be established.		
Reviews medical records for objective data such as labs, brain imaging, and recent echocardiogram.		
Discusses the anesthetic concerns and plan with the surgical intern and attending, addressing the need for a pre-induction arterial line and larger bore intravenous access.		
Places a pre-induction large-bore intravenous line; considers using advanced ultrasound guidance.		
Places a pre-induction arterial line; considers using advanced ultrasound guidance; may request femoral arterial line access.		
Begins pre-oxygenation by placing mask with machine circuit attached.		

(continued)

Table 35.1 (continued)

Communication with providers in a time-pressured environment		
Demonstrates ability to clearly convey the priorities to commence general anesthesia to the interventionalists and staff.		
Demonstrates understanding of the urgency of progressing with the case to optimize cerebral revascularization.		

Summary of Clinical Teaching Points

What is considered Non-Operating Room Anesthesia?

Non-Operating Room Anesthesia (NORA) refers to a variety of procedures performed outside of the traditional operating room. These procedures have traditionally been minor interventions on relatively healthy and stable patients, some not requiring the presence of an anesthesiologist. However, with the increasing volume of surgical procedures, the growing aging population with increasing comorbidity burden, and advancements in surgical techniques, there has been a shift to perform more and more procedures in the gastroenterology, radiology, cardiology, and neurology interventional suites.

What are some of the challenges of providing an anesthesia outside of the OR (OOR) or NORA? [1]

- Location: the procedure is taking place outside of the typical operating room, with equipment and supplies that may differ from what the anesthesiologist may be accustomed to. Moreover, these sites are often remotely located with limited workspace, and support staff that is not readily available.
- Personnel: many OOR procedures have traditionally been performed without the support of an anesthesiologist. Therefore, OOR) staff may not be trained to understand anesthesia, the skillset of an anesthesiologist, or how to recognize the rare but serious complications that may require an anesthesiologist, such as allergic reactions and especially deeper levels of sedation that increase the risk of upper airway obstruction and apnea.
- Communication: unfamiliar procedures, timing, and required resources are all scenarios predisposing to poor outcomes. It is imperative that the anesthesiologist have open communication with the proceduralist throughout the periprocedural period.
- Financial and operational constraints: the incentive to perform a high volume of cases within a given day is not insignificant. Even for emergent NORA procedures, it is prudent for the anesthesiologist to adequately plan and communicate the anesthetic requirements to the interventionalist to ensure that patient safety remains the priority.
- Monitoring: this should be held to the same standard as is maintained in the traditional operating room and as outlined by the American Society of Anesthesiologists (ASA). Equipment may be outdated, inadequate, or not functional. The anesthesiologist should set up and check the required equipment prior to delivering any anesthetic.

Because of the challenges outlined above, the incidence of adverse anesthesia outcomes has been noted to be higher in out of OR environments [2, 3]. Having an appreciation of the difficulties and pitfalls associated with these environments is a mandatory skillset that all anesthesia providers must obtain.

What are additional considerations for the preprocedural evaluation? [4]

According to the ASA Guidelines for pre-anesthesia evaluation, the preoperative evaluation should include the following:

- History (including medical, surgical, anesthetic, and medication) and physical exam.
- Review of diagnostic laboratory tests and other relevant studies.
- Assessment of ASA status.
- Clarifying nil per os (NPO) status.
- Formulation of an anesthetic plan that is conveyed to the patient along with the risks, benefits, and alternatives.

What information is needed prior to operating on a patient in the interventional radiology (IR) suite? [5]

- Identify whether the patient has any allergies to intravenous dyes.
- Women of childbearing age must be counseled on the theoretical risk of fetal safety.
- Location of protective gear for all staff. This includes lead aprons, thyroid protectors, lead glass wall, and radiation badges.
- Be aware of the location of emergency equipment, such as a cardiopulmonary emergency crash or code cart, automated external defibrillator, malignant hyperthermia cart, and difficult airway equipment.

What are the complications of cerebral revascularization? [5, 6]

- Hemorrhage: this may warrant reversal or correction of any coagulation abnormalities. Intracranial bleeding may also require burr holes or an emergent transport to the operating room for open craniotomy if elevated intracranial pressures become a concern.
- Vasospasm: this can be treated with vasodilators such as nitroglycerine or calcium channel blockers.
- Occlusion of the vessel or clot propagation: this may require the provider to raise the blood pressure pharmacologically to support cerebral perfusion pressure.
- Acute hemodynamic changes such as bradycardia or asystole from vagal stimulation intracranially.
- Cerebral hyperperfusion syndrome: this may present with ipsilateral headache, seizures, or focal neurological deficits. Cerebral perfusion is pressure-dependent in this syndrome. Strict blood pressure control is recommended; an example is a balance of keeping systolic blood pressure below 120 mmHg adjusting it to be about 80% of the preoperative systolic pressure. Direct vasodilators such as calcium channel blockers, nitroprusside, and glyceryl trinitrate may induce cerebral vasodilation, increase cerebral perfusion, and worsen this syndrome.

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Chapter 36
Epiglottitis (Pediatric)

Phil Yao and Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Understand why epiglottitis is an airway emergency.
2. Identify differential diagnoses for upper airway obstruction.
3. Understand why muscle relaxation is contraindicated in airway management of epiglottitis.
4. Identify alternative methods for airway management in upper airway obstruction.

Simulator Environment

1. Location: children's hospital emergency room (ER) and then operating room (OR).
2. Manikin setup:
   (a) Age: child.
   (b) Lines: none initially.
   (c) Monitors: pulse oximetry on arrival.

The original version of this chapter was revised. A correction to this chapter can be found at https://doi.org/10.1007/978-3-030-95338-6_38

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3. Medications available: normal saline, propofol, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, atropine, dexamethasone.
4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, gum elastic bougie, laryngeal mask airway (LMA), suction with Yankauer tube, soft suction catheter, needle cricothyroidotomy kit, and tracheostomy setup.
   (b) Monitors: pulse oximeter, blood pressure cuff, 3-lead electrocardiogram (EKG), capnogram, temperature.
   (c) Lines: none.
   (d) Crash cart with defibrillator.
   (e) Paperwork: pre-operative anesthesia evaluation and physical exam.

Actors

1. Patient's mother in the emergency room.
   (a) The patient's mother is appropriately concerned.
2. Ear/nose/throat surgeon in the operating room.
3. Nurses in the emergency room and operating room.
   (a) The nurses are helpful and attentive.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist being called to the emergency department for a 4-year-old presenting with fever, stridor, and significant drooling after eating some tater tots.
   (b) Preoperative history: previously healthy, received full vaccinations.
   (c) Physical appearance: vigorous boy, sitting upright and breathing with an open mouth and protruding tongue.
   (d) Preoperative vital signs: heart rate (HR) 100, blood pressure (BP) 100/55, oxygen saturation (SpO_2) 99% on room air, temperature 39 °C.
2. Scenario development
   (a) Phase 1: initial assessment of airway obstruction in the emergency room.
      (i) The learner will determine if the patient can maintain oxygenation and spontaneous ventilation by doing the following:
         1. Assessing vital signs including oxygen saturation, heart rate, blood pressure.

2. Assessing quality and frequency of respirations.
3. Auscultating the patient's heart and lungs.
4. Examining the oropharynx with proper personal protection equipment.
5. Obtaining a detailed history from the mother specifically concerning onset of symptoms and any past upper respiratory infections.
6. Understanding that the recent ingestion of tater tots would not cause significant fever that is present in this child and to not be distracted by this.
7. Reassessing frequently to determine the rate of deterioration.

(ii) The learner will decide whether additional imaging is necessary.

1. If the learner asks for a computed tomography (CT) scan, the learner will be informed that the patient cannot tolerate lying flat at all and only feels comfortably breathing in an upright, tripod position, leaning forward.
2. If the learner asks for lateral neck radiographs, a radiograph image will be provided.

   (a) The learner should identify the classic "thumb sign" as indicative of a narrowing of the epiglottic space from inflammation.

3. The learner should recognize that while imaging can help establish the diagnosis of epiglottitis, interventions should not be delayed if the patient is unstable or deteriorating

(iii) If the learner does not initiate transfer to the operating room, then the emergency room nurse will prompt the learner by asking them how soon the patient can be transferred to the operating room.

(iv) When transfer to the operating room is initiated, the learner should clearly communicate what needs to be prepared, including the following:

1. Calling for ear/nose/throat surgeon to be present at all times. The learner should discuss having the surgeon scrubbed and prepared with surgical equipment on hand for an emergency cricothyroidotomy should the anesthesiologist lose control of the airway and be unable to oxygenate or ventilate.
2. Calling for difficult airway equipment, which includes video laryngoscopes, fiberoptic bronchoscopes, endotracheal tubes of various sizes, laryngoscopes of various sizes and types, stylets, a needle cricothyroidotomy kit, and a tracheostomy setup to be prepared prior to induction.

(b) Phase 2: induction and intubation in the operating room.

(i) The learner should decide on mask induction while maintaining spontaneous ventilation. It is of utmost important that a patient who has an upper airway obstruction is kept spontaneously ventilating.

(ii) The learner should keep the patient seated during induction. If they do not, then the scenario will proceed to Phase 3 below.

1. Laying the patient supine can precipitate complete upper airway obstruction.
2. Having the parent hold the patient can be helpful for an anxious child. It is important to minimize agitating or upsetting the child, which could result in exacerbation of the upper airway obstruction.

(iii) The learner should place a peripheral intravenous (PIV) line after inhalational induction.

1. The learner should have the most experienced person in the room place the PIV so it can be done as quickly as possible.

(iv) The learner should avoid muscle relaxants prior to intubation. If the learner administers muscle relaxants prior to intubation, then the scenario will go to Phase 3 listed below.

1. Adequate depth of anesthesia for intubation can be achieved with a combination of inhaled anesthetics such as sevoflurane and intravenous agents such as propofol, dexmedetomidine, and ketamine.
2. Giving muscle relaxants before intubation can precipitate complete upper airway obstruction.

(v) For choice of equipment for first intubation attempt, the learner may select direct laryngoscopy or video laryngoscopy. The learner should downsize their initial endotracheal tube selection in anticipation of a narrowed glottic opening.

(c) Phase 3: airway emergency – inability to intubate and inability to ventilate.

(i) Regardless of choice of equipment, the learner will be unable to intubate.
(ii) The patient's airway will become completely obstructed despite patient efforts at spontaneously ventilation.
(iii) The learner should recognize severe upper airway obstruction and inability to intubate.
(iv) The learner will attempt to mask ventilate but will be unsuccessful, even with use of airway adjuncts and two-handed mask ventilation.
(v) Oxygen saturation and heart rate will begin to drop.
(vi) The learner should identify inability to intubate and inability to ventilate.
(vii) The learner should notify the surgeon of loss of control of the airway and ask them to prepare for emergency cricothyroidotomy or tracheotomy.
(viii) The learner should simultaneously administer epinephrine to avoid cardiac arrest as the hypoxemia and hypercarbia worsen.

(ix) After emergency cricothyroidotomy or tracheostomy, the patient's heart rate and oxygenation will improve.
(x) Bacterial cultures should be drawn once the airway is secured.
(xi) High dose intravenous steroids such as methylprednisolone, dexamethasone, or hydrocortisone should be given to decrease airway edema.

Scoring Rubric

Table 36.1 Scoring rubric for case scenario on Epiglottitis

Topic: Epiglottitis (Pediatric)		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not completed
Initial airway assessment		
Performs efficient pre-operative history and physical examination in the emergency department.		
Attempts to establish rapport with patient and parent. Tries to avoid agitating or upsetting the patient.		
Assesses whether intubation is necessary.		
Administers supplemental oxygen: 100% fraction of inspired oxygen (FiO_2) via face mask.		
Identifies epiglottitis.		
Orders appropriate imaging studies pending patient stability.		
Calls to transfer patient to the operating room in a timely fashion.		
Calls for appropriate equipment to be set up in the operating room, including difficult airway equipment (video laryngoscope, fiberoptic bronchoscope, downsized endotracheal tubes, various size and types of laryngoscopes, emergency cricothyroidotomy tray) and presence of ear/nose/throat surgeon.		
Induction		
Performs calm inhalational induction in a seated position that is comfortable for the patient.		
Identifies the most experienced provider to place peripheral intravenous line as quickly as possible.		
Does not administer muscle relaxation prior to intubation.		
Preferentially uses video laryngoscope for first intubation attempt to minimize airway trauma needed to establish view of glottic opening.		
Downsizes endotracheal tube in anticipation of narrowed glottic opening.		

(continued)

Table 36.1 (continued)

Airway emergency		
Attempts to mask ventilate using two-handed mask ventilation when recognizes failed one-handed mask ventilation. May use airway adjuncts.		
Recognizes that patient is in a "cannot intubate, cannot ventilate" emergency airway situation.		
Avoids the use of a laryngeal mask airway.		
Identifies bradycardia is due to hypoxemia.		
Administers intravenous epinephrine to prevent cardiac arrest.		
Notifies the surgeon immediately of loss of control of the airway.		
Requests that surgeon perform emergency cricothyroidotomy or tracheostomy.		

Summary of Clinical Teaching Points

What is epiglottitis? [1, 2]

- Epiglottitis is caused by bacterial infection with Hemophilus influenzae type b (most common), Hemophilus influenza type A, F, and non-typable, Streptococci, or Staphylococcus aureus.
  - The incidence of epiglottitis has significantly decreased with vaccinations.
  - Single nucleotide polymorphisms of IL-10 have been associated with vaccine failure.
  - Prior to widespread vaccine administration, epiglottitis was most common among children age 3–5 years old, but is now more common in adults.
- Non-infectious etiologies of epiglottitis include thermal injury, foreign body, and caustic ingestion.
- Inflammation of the epiglottis and aryepiglottic folds lead to upper airway obstruction in children.
- Epiglottitis is an airway emergency because obstruction can evolve rapidly leading to hypoxemia, hypercarbia, and subsequent cardiopulmonary arrest.

What is the differential diagnosis for epiglottitis?

- Viral laryngotracheobronchitis (croup)
- Bacterial tracheitis
- Retropharyngeal abscess
- Foreign body
- Diphtheria
- Ludwig Angina

What can best optimize the chances of first pass success for intubation? [1, 2]

- Perform the intubation attempt in the operating room.

- Position the patient in the sitting position.
- Uses cuffed endotracheal tube that is 1–2 sizes smaller than predicted by age.
- Avoids muscle relaxation.

What should be prepared in a known difficult airway? [2]

- Call for ear/nose/throat surgeon to be present in the operating room prior to induction of anesthesia.
- Prepares difficult airway equipment prior to induction: video laryngoscope, fiberoptic bronchoscope, downsized endotracheal tubes, various size and types of laryngoscopes, emergency cricothyroidotomy tray.
- Percutaneous needle cricothyroidotomy is the preferred method of surgical cricothyroidotomy in children under the age of 12 because of increased risk of damage to important structures due to anatomic differences in the pediatric airway:
  - Smaller and shorter
  - Anterior and cephalad
  - Funnel-shaped with most narrow at the cricoid cartilage

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Chapter 37
Neonatal Abdominal Wall Defects (Pediatric)

Phil Yao and Claire Sampankanpanich Soria

Case Outline

Learning Objectives

1. Understand differences between omphalocele and gastroschisis in neonates.
2. Describe preoperative optimization for omphalocele and gastroschisis.
3. Understand the importance of intraoperative fluid and temperature regulation in neonates.
4. Recognize how to diagnosis abdominal compartment syndrome.

Simulator Environment

1. Location: operating room of a children's hospital
2. Manikin setup:
   (a) Age: newborn.
   (b) Lines: 1 × 24 Gauge (G) peripheral intravenous (PIV) line that is functional.
   (c) Monitors: none on patient at start of case.
3. Medications available: normal saline, propofol, succinylcholine, rocuronium, epinephrine, albuterol, fentanyl, atropine.

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4. Equipment available
   (a) Airway equipment: ventilator, face mask, laryngoscope and cuffed and uncuffed endotracheal tubes (ETTs) of various sizes, stylets, oral airway, nasal trumpet, laryngeal mask airway (LMA), suction with Yankauer, soft suction catheter.
   (b) Monitors: pulse oximeter on right thumb, blood pressure cuff, 3-lead electrocardiogram (EKG), capnogram, temperature.
   (c) Lines: 1 × 24 G PIV, 250 cc bag of normal saline (NS) on a Buretrol tubing.
   (d) Crash cart with defibrillator
   (e) Paperwork: pre-operative anesthesia history and physical examination.

Actors

1. Scrub tech
   (a) The scrub tech is busy opening trays and making lots of noises in the background during induction.
2. Circulator nurse
   (a) The nurse is helpful and attentive.
3. Surgeon
   (a) The surgery attending is asking lots of questions of the surgery fellow in the background about the size of the omphalocele.
4. Medical student on anesthesia rotation
   (a) The medical student has never taken care of a newborn before and is very worried about the baby having pain, so they offer to dilute some fentanyl for you to give.

Case Narrative

1. Scenario background given to participants:
   (a) You are the anesthesiologist starting a case of a 3-day-old, 3.5 kg baby boy transferred from the neighboring OB hospital for a 7 cm omphalocele.
   (b) Preoperative history: ex-full term; no recent upper respiratory infection (URI) symptoms; nil per os (NPO) since admission 24 h ago; hasn't eaten since admission.
   (c) Preoperative physical: vigorous baby boy, crying in his mother's arms, normal appearing facies.
   (d) Lines/drains/airways: 1 × 24 G PIV in the hand, nasogastric tube.
   (e) Preoperative vital signs: heart rate (HR) 140 beats per minute (bpm), blood pressure (BP) 80/55, oxygen saturation (SpO_2) 99% on room air, temperature 37 °C

(f) Preoperative labs: sodium (Na) 140, chloride (Cl) 109, potassium (K) 4.5, bicarbonate (HCO_3) 24, creatinine (Cr) 0.8, glucose 90, hemoglobin (Hb) 14, platelets 300 K
(g) Preoperative imaging: none performed.

2. Scenario development

(a) Phase 1: preoperative assessment

(i) The surgery team will be eager to start surgery and will try to rush the learner to bring the patient from the pre-operative area to the operating room.
(ii) The learner must inquire about preoperative labs and imaging. Upon confirming that imaging has not been performed, learner may request that the case be delayed until the following diagnostic studies are performed: transthoracic echocardiogram, kidney ultrasound, and head ultrasound.
(iii) If the learner attempts to start mask induction, have the circulator nurse tell a story about a previous patient scheduled to have this surgery but ending up being canceled and rescheduled for heart surgery first.
(iv) If learner does not respond to prompt, have the circulator nurse explicitly ask the surgery team about whether an echocardiogram is necessary in this patient.
(v) The learner should have a discussion with the surgeon emphasizing the importance of having diagnostic studies to rule out congenital cardiac disease or other anatomic abnormalities that may be associated with the omphalocele.
(vi) Imaging and studies will show a small 3 mm VSD, normal kidneys, and unremarkable head scan.

(b) Phase 2: induction and intubation

(i) Induction: the learner should recognize the importance of intubating the patient in a timely fashion to minimize the risk of aspiration, while also recognizing that neonates have a rapid time to oxygen desaturation.

1. Induction agents of choice:

(a) Propofol 2–3 mg/kg
(b) Ketamine 1–2 mg/kg
(c) Fentanyl 1 mcg/kg

2. Paralytics will be required especially when attempting to internalize the omphalocele.

(a) Rocuronium
(b) Succinylcholine can be used for intubation, but will not provide muscle relaxation for the duration of the case.

3. Narcotics can be long-acting because the patient will remain intubated after the surgery and transported back to the neonatal intensive care unit (NICU) intubated.

4. The learner may choose to pre-treat with atropine 20 mcg/kg to prevent bradycardia, in anticipation of a potential delay in intubating the patient and developing hypoxemia and subsequent bradycardia.

(ii) The learner can choose to suction and then remove the nasogastric tube prior to intubation. Regardless, the baby will vomit during direct laryngoscopy.

1. To manage aspiration during induction, the learner should turn the baby on the side in right or left lateral decubitus and suction the oropharynx.

(iii) The learner should move to intubate as fast as possible.
(iv) The learner may mask ventilate prior to intubation due to concern for oxygen desaturation during the aspiration event.
(v) After intubation, the learner should pass a soft suction catheter down the endotracheal tube to remove potential aspirate.

(c) Phase 3: perioperative management

(i) The learner may choose to place a second peripheral IV, to use one as a bolus line for crystalloids, colloids, and/or blood transfusion as indicated, and one to use as a maintenance line for dextrose-containing solution to prevent hypoglycemia.

1. The learner should recognize that an open abdomen can result in fluid losses of 8–10 cc/kg/h.
2. The learner should start with a 20 cc/kg bolus of crystalloid fluids, which may include lactated ringers, normal saline, or plasmalyte.
3. The learner should run a dextrose-containing solution as maintenance fluid at a rate of 4 cc/kg/h. Example solutions include D5 ½ NS, which is 5% dextrose and half-normal saline.
4. The learner should ensure that crossmatched packed red blood cells are available prior to start of surgery, in case of surgical bleeding.

(ii) The learner may decide that given the patient's normal cardiac function and anatomy on preoperative echocardiogram, the patient does not require an arterial line.
(iii) After the learner is ready for the surgeons to prep and drape, the baby is moved down to the middle of the table.
(iv) The patient's temperature will begin to drop on the monitors.

1. If the learner did not insert a temperature probe, have the surgeon mention that the child feels cold.
2. The learner should perform the following interventions to maintain normothermia: underbody forced air warmer; increased room temperature; covering the baby with plastic drapes; asking the surgeon to remove any liquid skin preparation solution from the patient's body to minimize evaporative cooling; ensuring there is

appropriate placement of a temperature probe, such as a rectal temperature probe.

(d) Phase 4: diagnosing abdominal compartment syndrome

(i) Surgery is over and the abdomen is closed. The surgeon will ask the anesthesiologist how the patient is doing.
(ii) The learner should check their ventilator settings to see if tidal volumes are appropriate and if they have decreased significantly since abdominal closure. The tidal volumes will be slightly decreased and the patient will require a slight increase in driving pressure on pressure-controlled ventilation settings, but the learner will be able to ventilate and oxygenate appropriately.
(iii) Vitals have been stable. The patient is transferred intubated on a transport ventilator to the NICU.
(iv) A few hours later, the intensivist is paged due to heart rate in the 220 s, inspiratory pressure of 30 cm H2O on the ventilator, and failing pulse oximetry.
(v) Pertinent physical exam findings of distended abdomen with diminished bilateral dorsalis pedis pulses.
(vi) The anesthesiologist and surgeon will be called to NICU bedside.
(vii) The learner should recognize signs of abdominal compartment syndrome and discuss with the surgeon a plan for abdominal decompression, to be done at bedside or return to the operating room, pending patient stability.
(viii) The learner may administer muscle relaxant and initiate inotropes to support hemodynamics while the surgeons prepare for abdominal decompression. The scenario will end here.

Scoring Rubric

Table 37.1 Scoring rubric for case scenario on Neonatal Abdominal Wall Defects

Topic: Neonatal Abdominal Wall Defects		
Participant Name:		
Evaluator Name:		
Score:		
	Completed	Not completed
Preoperative assessment		
Asks about echocardiogram, kidney ultrasound, and head scan.		
Delays case for imaging studies.		
Assesses volume status and bolus fluid prior to induction.		

(continued)

Table 37.1 (continued)

Induction		
Selects appropriate induction medications, and evaluates pros/cons of muscle relaxation and narcotics.		
Recognizes aspiration risk and places suctions nasogastric tube prior to induction.		
Recognizes aspiration, repositions and suctions patient.		
Intubates in a timely fashion.		
After intubation, suctions the endotracheal tube (ETT) for aspirate.		
Maintenance phase		
May place a second peripheral intravenous line.		
Maintains thermoregulation. Recognizes hypothermia and takes appropriate steps to correct temperature: drapes, forced air warming blanket, warmed room.		
Avoids the use of nitrous oxide due to possibility of gastric distention and pulmonary hypertension in a neonate.		
Adequately fluid resuscitates patient, starting with fluid bolus of 20 cc/kg of crystalloid.		
Ensures crossmatched packed red blood cells are available prior to start of surgery.		
Establishes an objective measure of fluid status and fluid loss.		
Identifies predictors of successful primary closure. Communicates with surgeon regarding ventilation after closure.		
Recognizes slight decrease in compliance from restrictive ventilatory defect with abdominal closure. Adjusts driving pressure appropriately.		
Abdominal compartment syndrome		
Recognizes abdominal compartment syndrome.		
Communicates with surgeons about plan for abdomen decompression, to be done at bedside or return to the operating room pending patient stability.		
Re-doses muscle relaxant and supports hemodynamics with fluids/blood and inotropes/pressors as needed.		

Summary of Clinical Teaching Points

How are gastroschisis and omphalocele different from each other?

Table 37.2 Comparison of gastroschisis versus omphalocele

	Gastroschisis	Omphalocele
Etiology	Vascular abnormality	Failure of gut to return to the abdomen
Sac	No	Yes
Location	Right lateral to umbilicus	Midline
Maternal age	<20 years old	>40 years old
Timing of surgery	Within hours after birth	Not emergent/urgent unless >10 cm

What are general preoperative concerns for neonatal abdominal wall defects?

- Fluid resuscitation
  - Signs of volume stasis: capillary refill, urine output, heart rate, and blood pressure.
  - Bolus isotonic fluids: a good starting point is 20–40 cc/kg. Examples include lactated ringers, normal saline, and plasmalyte.
  - Maintenance fluids should contain glucose. Examples include 5% dextrose in normal saline. Maintenance rate should be 4 cc/kg/h.
  - Labs: electrolytes and acid-base balance; acidosis may indicate hypoperfusion and is usually accompanied by an elevated lactate.
- Temperature regulation
  - Warmed room
  - Forced air warming blanket
  - Covers such as surgical drapes, plastic drapes, and bags to enclose the bowel, to prevent heat loss and evaporation of fluid.
- Sepsis: discuss antibiotics with the surgical team.
- Full stomach and aspiration risk: decompress with a nasogastric tube prior to induction and intubation.

What are preoperative considerations specifically for omphalocele?

- Omphaloceles are covered and will have less risk of infection or electrolyte imbalance.
- Omphaloceles are associated with other defects:
  - Trisomy: 13, 14, 15, 18, or 21.
  - Pentalogy of Cantrell: anterior diaphragmatic hernia, sternal cleft, ectopia cordis, intracardiac defect.
  - Beckwith-Wiedemann syndrome: macroglossia, umbilical hernia, hypoglycemia.
  - OEIS complex (omphalocele-exstrophy-imperforate anus): bladder exstrophy, imperforate anus, spinal defect

- Echocardiogram, kidney ultrasound, karyotyping and head scan should be obtained before surgery.
- Patient may be a difficult airway due to congenital defects, so a careful airway exam should be performed.

What are intraoperative considerations?

- Airway: treat as full stomach and perform rapid sequence intubation, with the recognition that neonates will poorly tolerate any period of apnea and will have rapid oxygen desaturation.
  - Muscle relaxant options: rocuronium 1.2 mg/kg, succinylcholine 1–2 mg/kg.
  - Hypnotics and analgesics: propofol 2–3 mg/kg, fentanyl 1 mcg/kg to start.
- Access
  - Multiple IV access for large volume resuscitation.
  - Arterial line is helpful for frequent lab draws, guiding fluid therapy, and if there are coexisting cardiac disorders.
- Anesthesia
  - Avoid nitrous oxide due to the possibility of gastric distension.
  - Caudal epidural block can be done, but is difficult to provide coverage above the level of the umbilicus (thoracic T10 level).
  - Ensure muscle relaxation to improve surgical conditions.

What is a rapid sequence induction?

- Often done in situations of a high-pressure stomach and high aspiration risk.
- Cricoid pressure is not helpful in a neonate.
  - It distorts the view, making intubation challenging.
  - It may stimulate vomiting if the patient is not well-anesthetized.
- There is very little time to intubate. Newborns will desaturate within less than 60 seconds.
- By definition, a rapid sequence induction avoids mask ventilation. Some providers administer small breaths after induction to prevent desaturation. This is controversial. However, if a patient is desaturating, it is more important to restore oxygenation and ventilation.

What do you do if the baby vomits during induction/intubation? [1]

- Turn the baby on their side – right or left lateral decubitus position – to prevent emesis from going down the trachea.
- Suction the oropharynx well.
- Intubate as fast as possible.
- After intubation, suction the endotracheal tube well. Provide positive end-expiratory pressure (PEEP).

How do you diagnose abdominal compartment syndrome in neonates? [2]

- Inspiratory pressures >25 cm H2O and decreasing tidal volumes
- Intragastric pressure > 20 mmHg
- Intravesicular pressure > 20 mmHg
- Decreasing MAPs from drop in preload
- Decreased peripheral circulation

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Chapter 35: Out of Operating Room Considerations and Neurointerventional Radiology (Adult) Primary author: Merrick Tan Secondary author: Minh Tran

Chapter 36: Epiglottitis (Pediatric) Primary author: Phil Yao Secondary author: Claire Sampankanpanich Soria

Chapter 37: Neonatal Abdominal Wall Defects (Pediatric) Primary author: Phil Yao Secondary author: Claire Sampankanpanich Soria

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