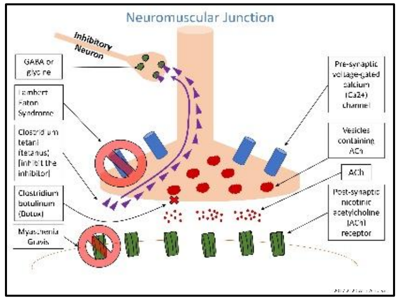
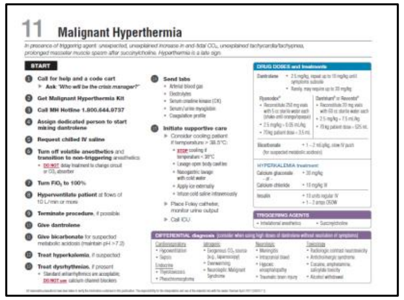




Room for notes

High-Yield Topics in Anesthesia

Medical Student Edition

Alexander Arriaga, MD, MPH, ScD
@AlexArriagaMD

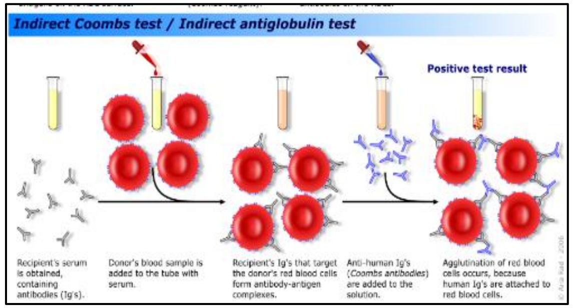


Image credits, where applicable, provided with slides for which they appear

Goal and Objectives

Overall Goal:

- To provide a data-driven and lifelong-learning style review of selected anesthesia topics, targeted at the medical student audience.

Objectives:

By the end of this session, participants should be able to:

- State anesthesia implications regarding selected high-yield anesthesia topics to guide further learning.
- Apply high-yield, evidence-based anesthesia knowledge towards lifelong learning in anesthesia.

This talk represents of the presenter and not necessarily the supporting agencies (views=mine). Dr. Arriaga is an Editor on the Patient Safety Editorial Board for the American Society of Anesthesiologists, and a Question Editor/Board Examiner for the American Board of Anesthesiology, both of which provide a stipend for work that is otherwise done in a volunteer capacity. The presenter does not believe that any of these represent a conflict of interest. All reasonable precautions have been taken to verify the information contained in this lecture. The responsibility for the interpretation and use of the information lies with the reader.

Room for notes

Room for notes

Anesthesia online learning resource examples

- Anesthesiology textbooks (many freely available via online med school library):
  - <u>Comprehensive books</u>: Miller's Anesthesia; Clinical Anesthesia (Barash)
  - <u>Anesthesia implications of disease states</u>: Stoelting's Anesthesia and Co-Existing Disease; Anesthesia and Uncommon Diseases
  - <u>Subspecialty textbooks</u>: Coté and Lerman's A Practice of Anesthesia for Infants and Children; Chestnut's Obstetric Anesthesia
  - <u>Paperback books</u>: Morgan & Mikhail's Clinical Anesthesiology

- Websites with a variety of educational resources:
  - OpenAnesthesia® (www.openanesthesia.org)
  - UpToDate (www.uptodate.com)
  - Data-Driven Didactics (www.datadrivendidactics.org)

Attempts have been made to cite and squeeze references into individual slides, understanding that this makes slides crowded. Expanded citations/references for a given slide can be provided on request.

Format for this session and slides

__X

- Will review topics, by category. Weighted priority given to key topics.
  - *Numbers on upper right-hand corner signify that the slide addresses topics asked "X" number of times on anesthesiology in-training exams, based on publicly available data, "intended to help plan continuing medical education," "help…identify specific strengths and weaknesses," and/or "assist and support you in the design of your educational program."[1]*
- ***After years of experience reviewing (1) how to create a PowerPoint slide & (2) literature on methods of learning (including active learning): these slides are methodically created to prioritize the stated objective: a data-driven and lifelong-learning style anesthesia review.***
  - Attempts have been made to use no smaller than size 16pt font and provide open-space, with the stated objective taking priority.
- Trainees who have not done certain specialty rotations have generally enjoyed the "review" of something new.
- Feel free to ask questions.

1. American Board of Anesthesiology In-training reports, program summary keywords, and Gaps in Knowledge reports. The keywords are provided to programs nationwide and publicly available at www.openanesthesia.org. Gaps in Knowledge reports are also provided to programs nationwide and/or publicly available at www.theaba.org. For example: https://www.theaba.org/pdfs/ITE_Gaps_Knowledge_Report.pdf. Accessed Sept 24, 2020. The design of this educational program was informed by these keywords.

Room for notes

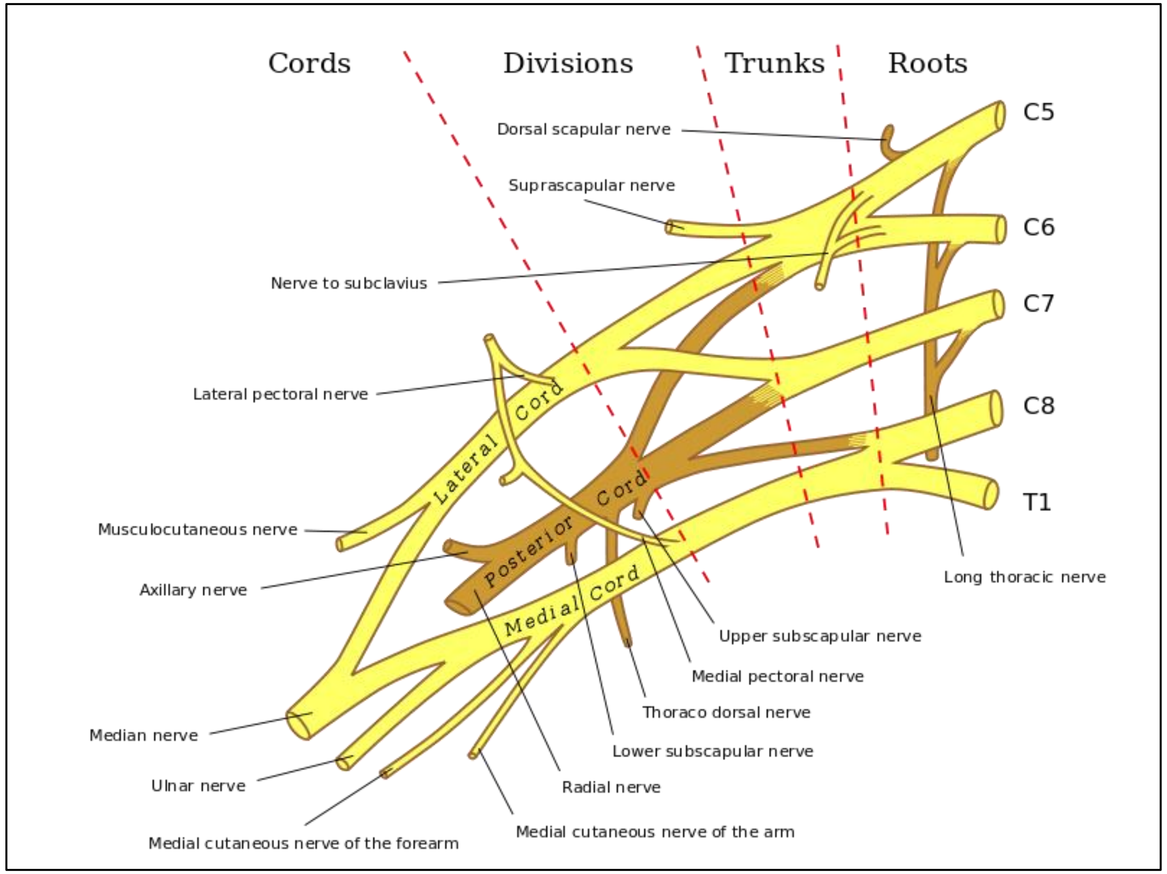
Room for notes

PBLD Stem Case 1

- A 27-year-old woman presents to the operating room for a rotator cuff repair. The surgeon asks the anesthesiologist to perform a peripheral nerve block for postoperative pain control.

- The medical student on the team remembers learning about the brachial plexus but is not familiar with nerve blocks. The anesthesiologist asks the medical student: What parts of the brachial plexus would be most relevant to shoulder surgery? The medical student asks you for help. What would be your advice?

Brachial Plexus Anatomy



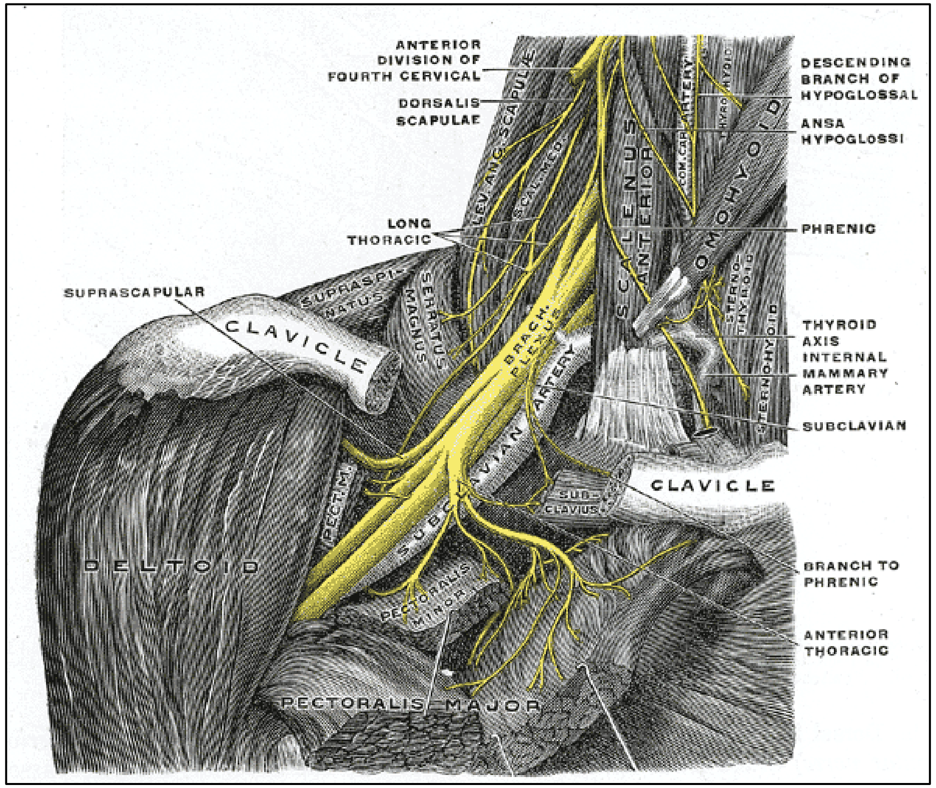
- Interscalene Block: Used for shoulder surgery. “Blockade occurs at the level of the **superior and middle trunks**….blockade of the inferior trunk (C8 through T1) is often incomplete”
- Supraclavicular Block: Used for surgery on elbow, forearm, and hand. “Blockade occurs at the **distal trunk-proximal division level**.”
- Axillary Block: “Indications…include surgery to the forearm and hand. Elbow procedures are also performed successfully using the axillary approach….Blockade occurs **at the level of the terminal nerves [branches]**.” [Miller Ch 57, 8th Ed] Axillary blocks often supplemented with blocks to musculocutaneous nerve and the intercostobrachial nerve (a branch of T2).

Brachial plexus image: Public domain, via Wikimedia Commons (https://commons.wikimedia.org/wiki/File:Brachial_plexus_2.svg)

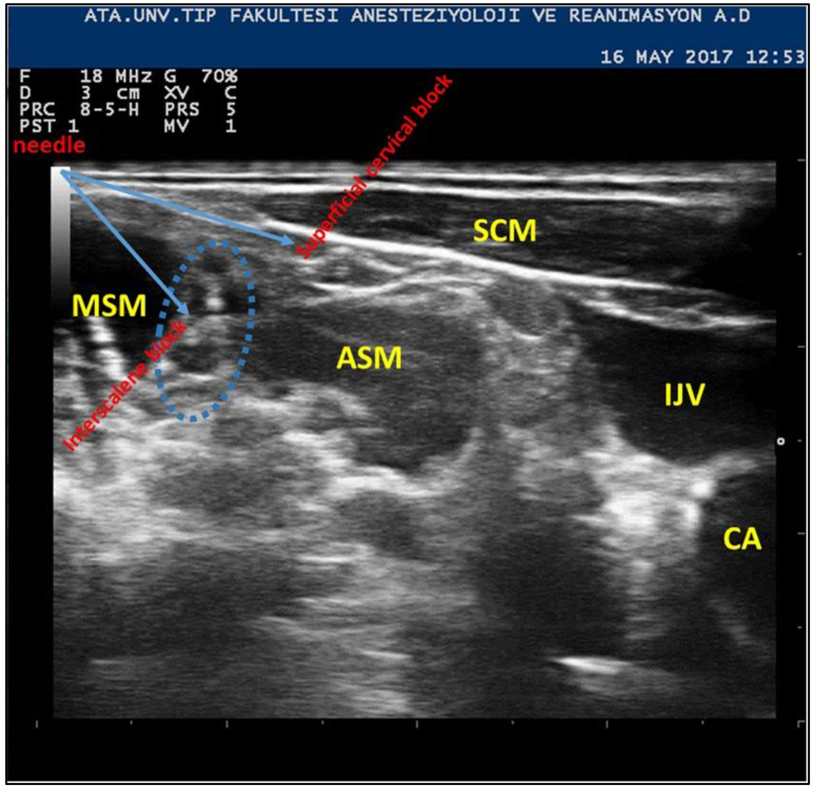
Room for notes

Interscalene & Superficial Cervical Plexus Block Anatomy

Anatomy



Ultrasound Anatomy



<u>Interscalene Block</u>:

- Often done for shoulder surgery in patients without major pulmonary disease.
- Blockade of inferior trunk (C8, T1 → ulnar nerve) can be incomplete. [Miller 9th Ed, Ch 46]

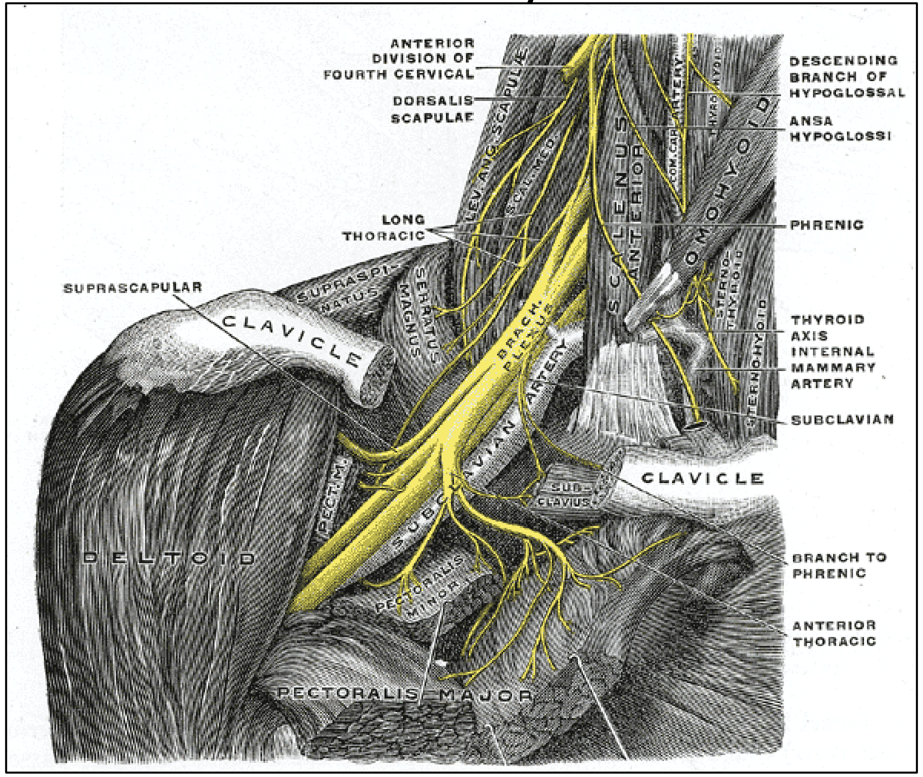
Anatomy image: Henry Vandyke Carter, https://commons.wikimedia.org/wiki/File:Gray808.png, Public domain, via Wikimedia Commons // Ultrasound Image: Kaciroglu et al. Kaciroglu, A. et al. Ultrasound-guided combined interscalene and superficial cervical plexus blocks for anesthesia management during clavicle fracture surgery. Ain-Shams J Anesthesiol 11, 28 (2019). https://doi.org/10.1186/s42077-019-0039-5. Creative Commons CC-BY-4.0.

Room for notes

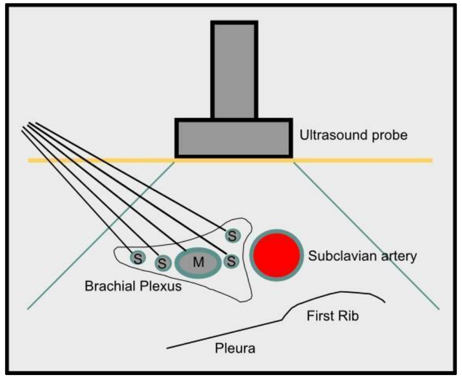
Supraclavicular Block Anatomy

Room for notes

Anatomy



Ultrasound Anatomy

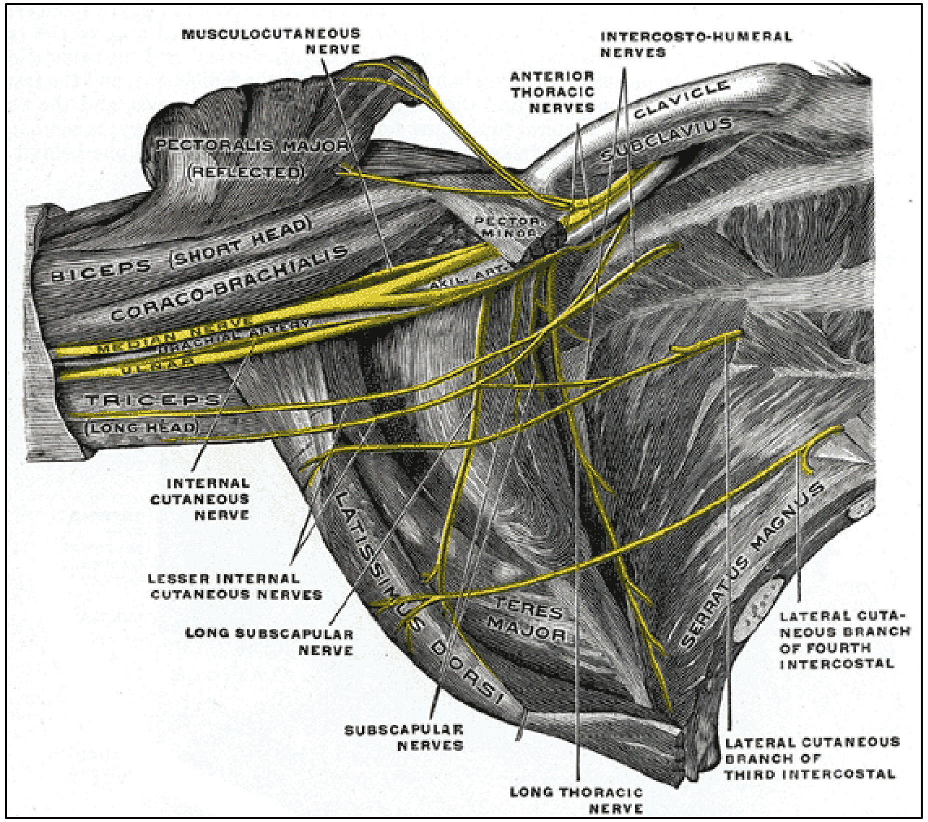


Anatomy image: Henry Vandyke Carter, https://commons.wikimedia.org/wiki/File:Gray808.png, Public domain, via Wikimedia Commons // Illustration: D'Souza et al. PMID: 30085598 Creative Commons CC-BY-4.0 // Photo: 729072025, used via license from Shutterstock.com // Ultrasound image: Change et al. PMID: 29083659. Creative Commons CC-BY-4.0

Axillary/Musculocutaneous Block Anatomy

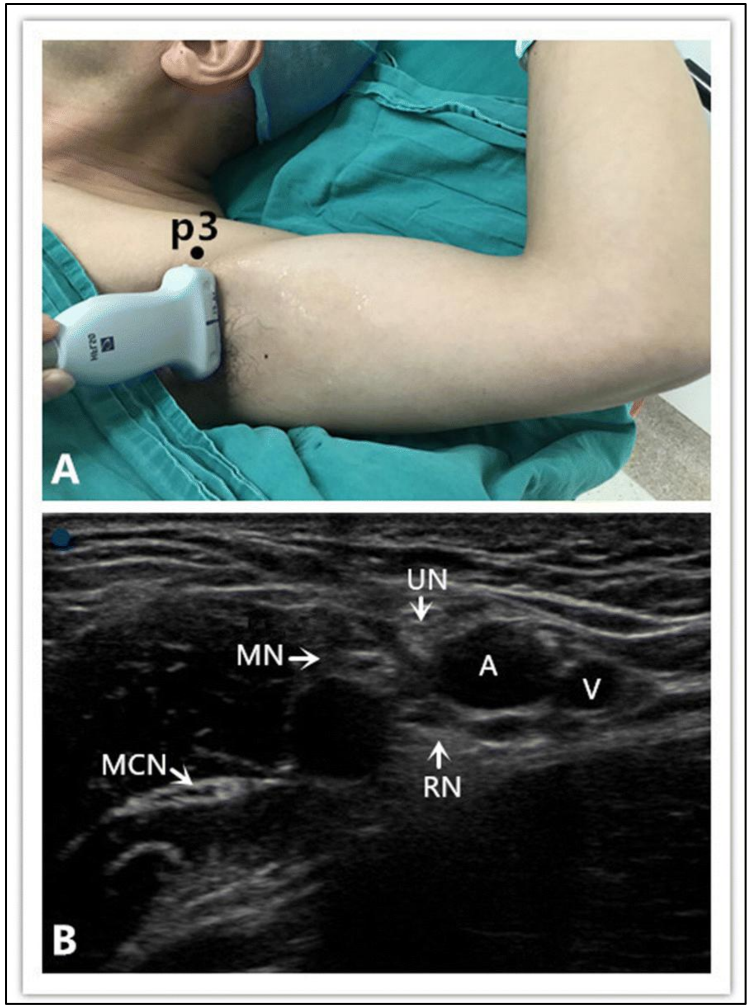
Room for notes

Anatomy



"Although anatomic variations exist, typically, the median nerve is found superior to the artery, the ulnar nerve is inferior, and the radial nerve is posterior and somewhat lateral…**At this level, the musculocutaneous nerve [sensory to lateral forearm] has already left the sheath** and lies with the coracobrachialis muscle."[1]

Ultrasound Anatomy



MCN: musculocutaneous nerve; MN: median nerve; UN: ulnar nerve; RN: radial nerve; A: axillary artery; V: axillary vein

Anatomy image: Henry Vandyke Carter, Public domain, via Wikimedia Commons; https://commons.wikimedia.org/wiki/File:Gray809.png // Ultrasound anatomy: Zhu et al. PMID: 30340524; Creative Commons CC-BY-4.0 // 1. Miller 9th Ed Ch 57

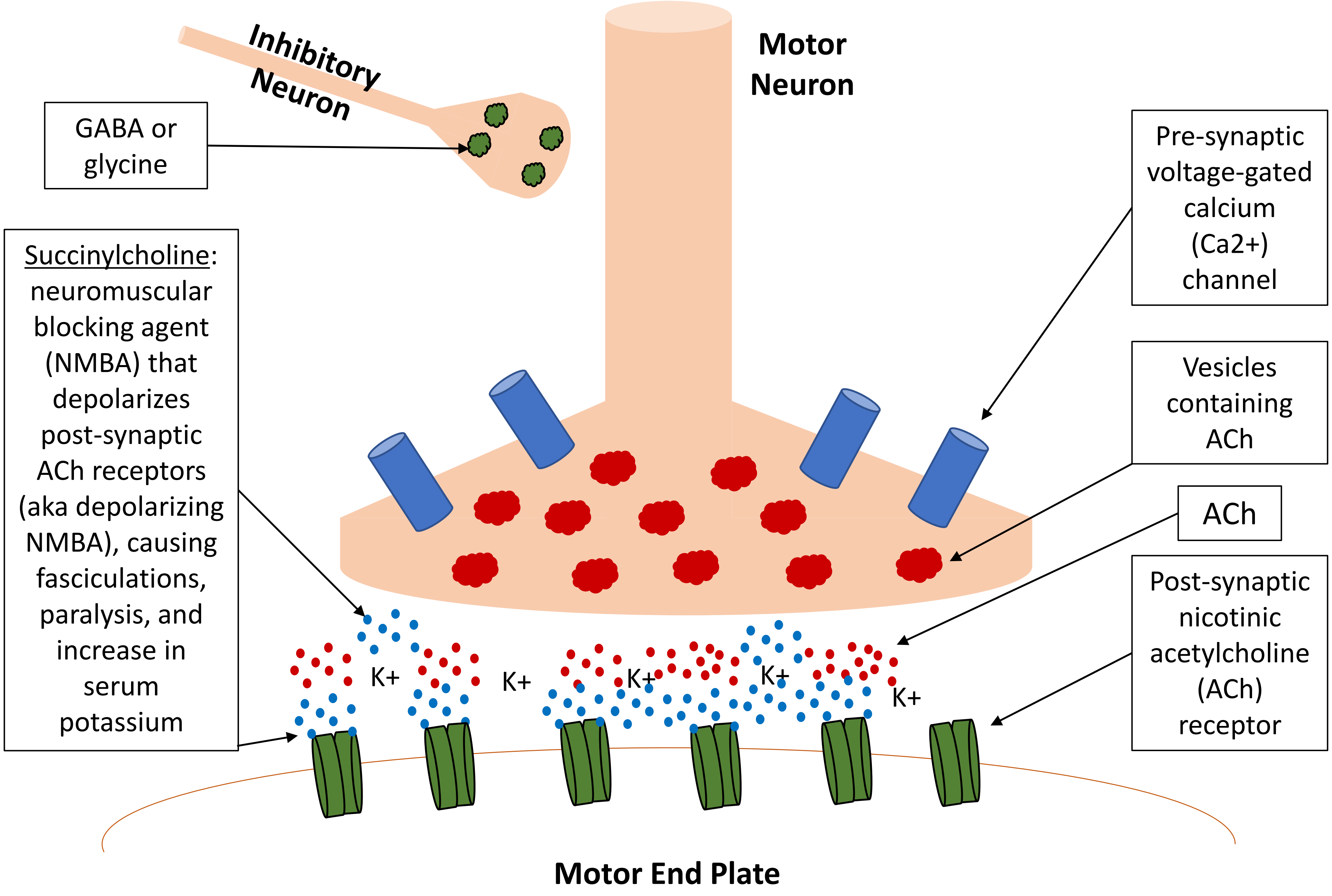
PBLD Stem Case 2

- A 45-year-old woman with myasthenia gravis (treated with pyridostigmine 180mg per day) presents for a laparoscopic appendectomy. She says she has a family history of malignant hyperthermia but does not know much details surrounding this.

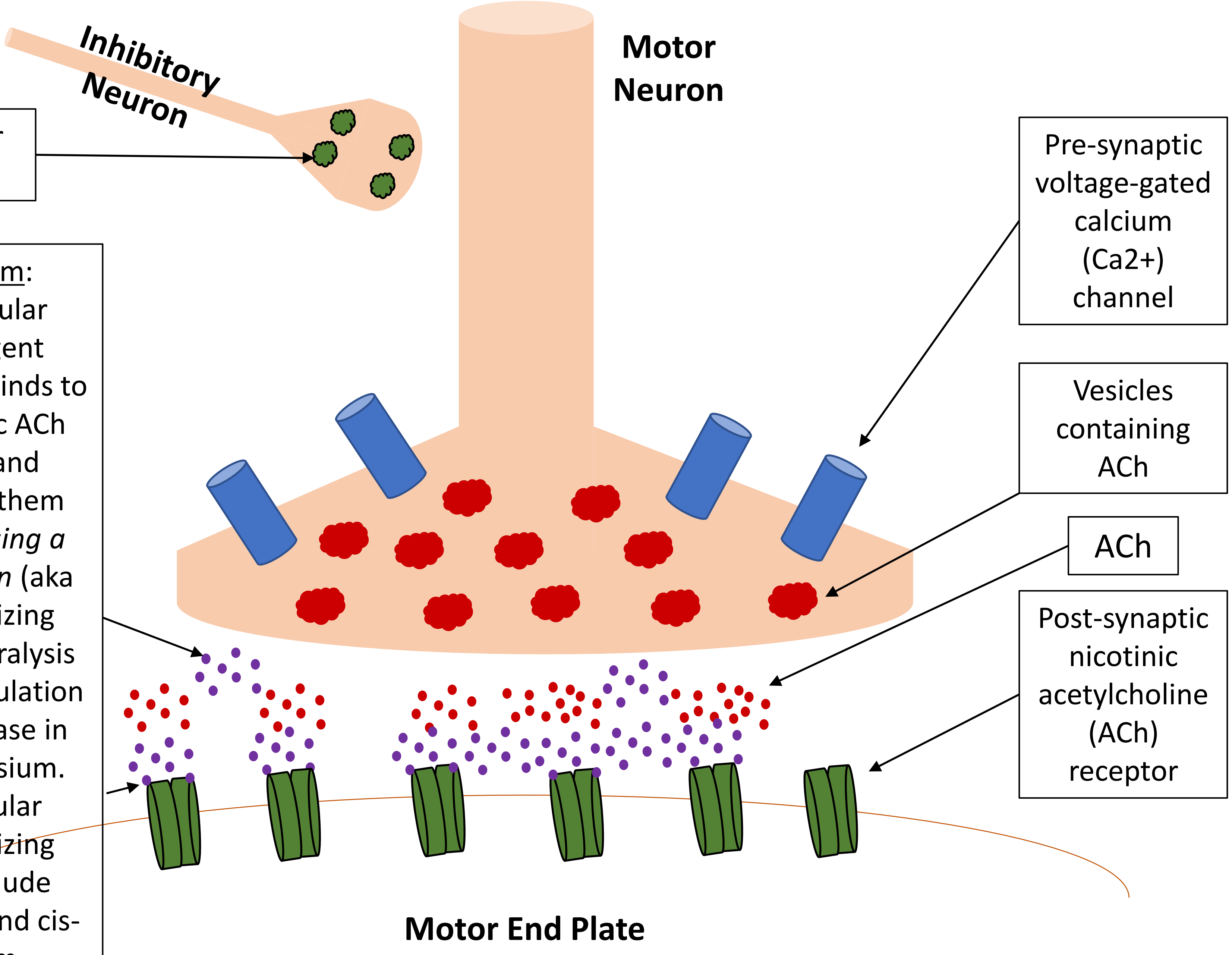
- The medical student on the case has not done anesthesia for a patient with myasthenia gravis and is not sure if the family history is relevant to the case. The medical student asks you for help. What would you advise?

Neuromuscular Junction and Succinylcholine

Room for notes



Neuromuscular Junction and Rocuronium

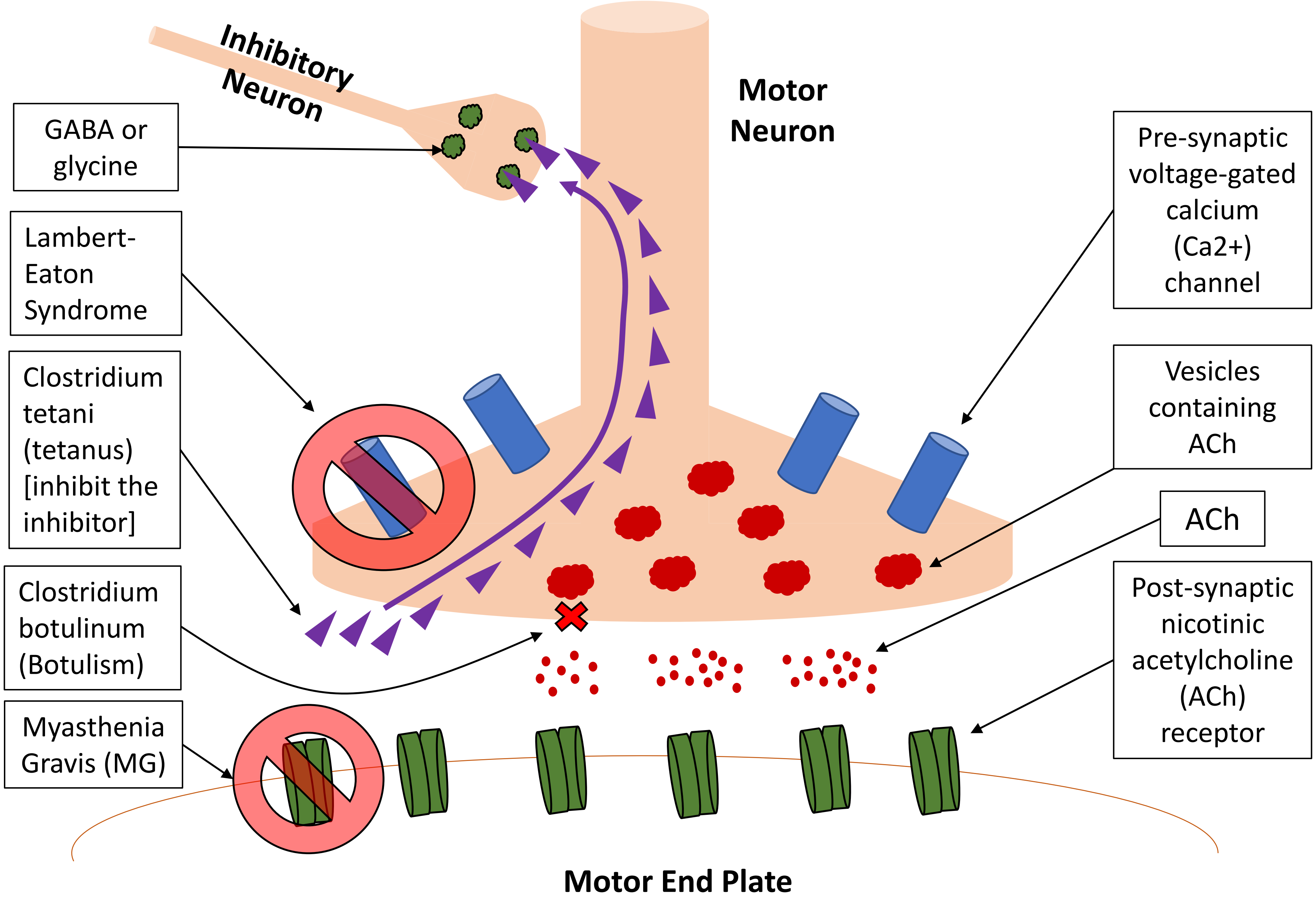


<u>Rocuronium</u>: neuromuscular blocking agent (NMBA) that binds to post-synaptic ACh receptors and antagonizes them *without causing a depolarization* (aka nondepolarizing NMBA) → paralysis with no fasciculation and no increase in serum potassium. Other popular nondepolarizing NMBA's include vecuronium and cis-atracurium.

Room for notes

<u>Sugammadex</u>: medication that can reverse the paralysis from rocuronium or vecuronium by forming a complex with these agents that can then be excreted by the kidneys.

"Image/Buzzwords Co-slides": Myasthenia Gravis, Lambert-Eaton, Botulism, Tetanus



Room for notes

"Image/Buzzwords Co-slides": Myasthenia Gravis, Lambert-Eaton, Botulism, Tetanus

29X

Room for notes

- Myasthenia Gravis (MG): autoantibodies against post-synaptic nicotinic acetylcholine receptors. **Resistant to succinylcholine** (decreased functional receptors)**; sensitive to nondepolarizers** (or unpredictable effect; sugammadex increasingly considered for reversal). Predictors for post-operative ventilation include:

Myasthenic History	Pulmonary History
Disease duration > 6 years	Other significant pulmonary disease
Bulbar (speech/swallow) symptoms preop	Vital capacity less than 2.9L
History of myasthenic crisis	
Pyridostigmine dose > 750mg/day	

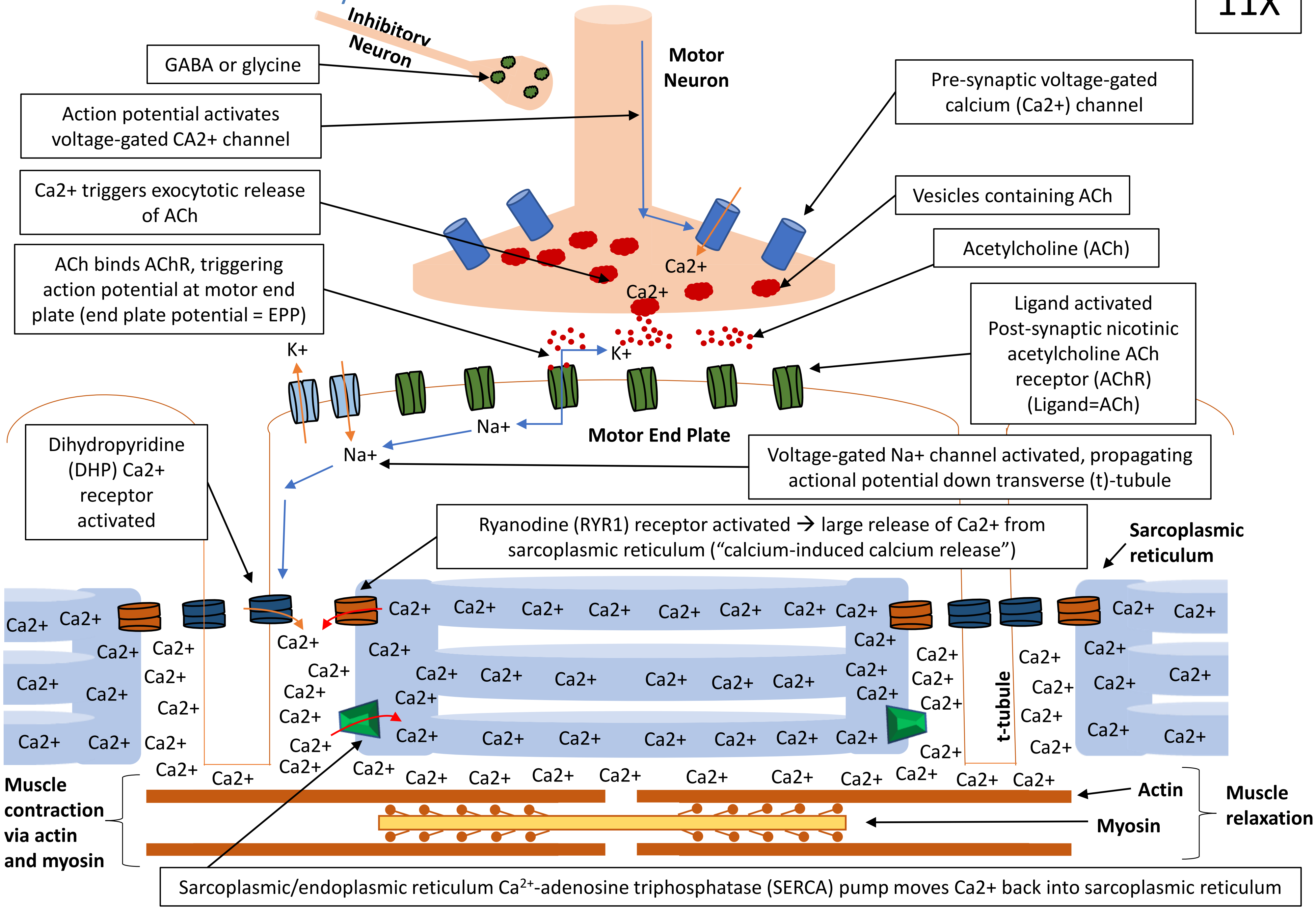
- Lambert-Eaton Myasthenic Syndrome: autoantibodies against presynaptic voltage-gated calcium channels. **Sensitive to succinylcholine AND sensitive to nondepolarizers**.
  - Often a paraneoplastic syndrome: small cell lung cancer is a common underlying malignancy.
  - Unlike MG: (1) more likely to have proximal limb weakness than respiratory, ocular, or bulbar; (2) strength increased with repeated effort; (3) autonomic dysfunction more likely.
- Clostridium botulinum (botulism) and Clostridium tetani (tetanus)
  - Botulinum toxin: neurotoxin prevents acetylcholine vesicle release from presynaptic membrane
    - Pain management: via muscle relaxation and reduction in spasticity
  - Tetanus: retrograde transport of toxin → preferentially affects inhibitory neurons → rigidity/spasms

Miller 9th Ed, Ch 35. // UptoDate: Anesthesia for the patient with myasthenia gravis. // Miller's Basics of Anesthesia, 7th Ed, Ch 43 // Berkowitz 2018; PMID: 30273248. // Patil et al 2016; PMID: 26879873.

Key Ions Involved in Neuromuscular Transmission

11X

Room for notes



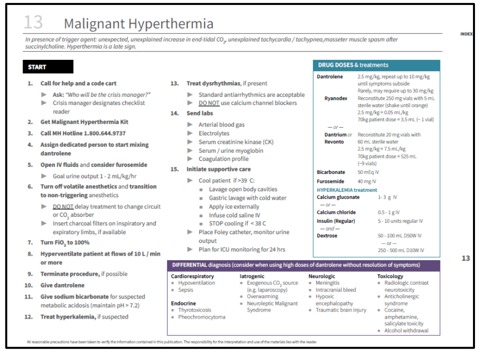
References: Miller's Anesthesia, 9th Ed, Ch 35 // Pollard's Cell Biology, 3rd Ed, Ch 17 // JIvory96, CC BY-SA 4.0, via Wikimedia Commons (https://commons.wikimedia.org/wiki/File:Ca2%2B_sparks.jpg) // https://en.wikipedia.org/wiki/File:NMJ_Signalling_1.jpg CC BY-SA 3.0 // https://open.oregonstate.education/aandp/chapter/10-3-muscle-fiber-excitation-contraction-and-relaxation/ CC BY-SA 4.0 // Litman RS et al. Anesthesiology 2018; PMID 28902673 // Roderick et al. PMID: 12781146.

Malignant Hyperthermia

17X

Room for notes

- Mechanism: abnormal RYR1 gene (most common) → abnormal ryanodine receptor → significant release of calcium from sarcoplasmic reticulum after triggering agent → uncontrolled muscle contractions → lactic acidosis → muscle breakdown causes hyperkalemia.
- Triggering agents: Volatile anesthetics (e.g., sevoflurane, desflurane, isoflurane), succinylcholine.
- ABG: mixed metabolic and respiratory acidosis (increased lactic acid; inability to hyperventilate enough to release CO_2).
- MH vs thyroid storm: Thyroid storm patient may have hyperthyroidism history. Thyroid storm is usually not associated with rigidity, elevated CK, or lactic acidosis. Hypokalemia (not hyperkalemia) is common in thyroid storm. ABG can be helpful.
- Known associated conditions include: Central/Multimini Core disease (Core Myopathies), King-Denborough syndrome (see Litman article for more).
- Testing options: (1) Muscle biopsy contracture studies (halothane, caffeine); (2) genetic testing.
- Dantrolene mechanism: complex; reduces pathologic concentrations of calcium. Can cause muscle weakness. "…whether dantrolene directly inhibits RyR1 or requires additional intermediates…remains to be clarified."[1] *Avoid calcium channel blockers in treatment of MH*.
- Handout: MH Crisis Checklist.
- QR Code: Litman RS et al. Anesthesiology 2018. PMID 28902673.



References: 1. Miller 9th Ed, Ch 35 // Barash 9th Ed, Ch 24 // Cote et al. A Practice of Anesthesia for Infants and Children. 6th Ed, Ch 41. // Openanesthesia: MH vs thyroid storm (available at https://www.openanesthesia.org/mh_vs-_thyroid_storm/) // Litman RS et al. Anesthesiology 2018; PMID 28902673 // Figure: Ariadne Labs Operating Room Crisis Checklists. See www.ariadnelabs.org for latest version. With permission via Creative Commons BY-NC-SA (https://creativecommons.org/licenses/by-nc-sa/4.0/).

13 Malignant Hyperthermia

In presence of trigger agent: unexpected, unexplained increase in end-tidal CO_2, unexplained tachycardia / tachypnea, masseter muscle spasm after succinylcholine. Hyperthermia is a late sign.

INDEX

START

1. **Call for help and a code cart**
   - **Ask:** *"Who will be the crisis manager?"*
   - Crisis manager designates checklist reader
2. **Get Malignant Hyperthermia Kit**
3. **Call MH Hotline 1.800.644.9737**
4. **Assign dedicated person to start mixing dantrolene**
5. **Open IV fluids** and **consider furosemide**
   - Goal urine output 1 - 2 mL/kg/hr
6. **Turn off volatile anesthetics** and **transition to non-triggering** anesthetics
   - DO NOT delay treatment to change circuit or CO_2 absorber
   - Insert charcoal filters on inspiratory and expiratory limbs, if available
7. **Turn FiO_2 to 100%**
8. **Hyperventilate patient at flows of 10 L / min or more**
9. **Terminate procedure,** if possible
10. **Give dantrolene**
11. **Give sodium bicarbonate** for suspected metabolic acidosis (maintain pH > 7.2)
12. **Treat hyperkalemia,** if suspected
13. **Treat dysrhythmias**, if present
    - Standard antiarrhythmics are acceptable
    - DO NOT use calcium channel blockers
14. **Send labs**
    - Arterial blood gas
    - Electrolytes
    - Serum creatinine kinase (CK)
    - Serum / urine myoglobin
    - Coagulation profile
15. **Initiate supportive care**
    - Cool patient if >39 C:
      - Lavage open body cavities
      - Gastric lavage with cold water
      - Apply ice externally
      - Infuse cold saline IV
      - STOP cooling if < 38 C
    - Place Foley catheter, monitor urine output
    - Plan for ICU monitoring for 24 hrs

DRUG DOSES & treatments

Dantrolene	2.5 mg/kg, repeat up to 10 mg/kg until symptoms subside Rarely, may require up to 30 mg/kg
Ryanodex	Reconstitute 250 mg vials with 5 mL sterile water (shake until orange) 2.5 mg/kg = 0.05 mL/kg 70kg patient dose = 3.5 mL (~ 1 vial)
— or —	
Dantrium *or* **Revonto**	Reconstitute 20 mg vials with 60 mL sterile water 2.5 mg/kg = 7.5 mL/kg 70kg patient dose = 525 mL (~9 vials)
Bicarbonate	50 mEq IV
Furosemide	40 mg IV

HYPERKALEMIA treatment

Calcium gluconate	1 - 3 g IV
— or —	
Calcium chloride	0.5 - 1 g IV
Insulin (Regular)	5 - 10 units regular IV
— and —	
Dextrose	50 - 100 mL D50W IV — or — 250 - 500 mL D10W IV

DIFFERENTIAL diagnosis (consider when using high doses of dantrolene without resolution of symptoms)

Cardiorespiratory
- Hypoventilation
- Sepsis

Endocrine
- Thyrotoxicosis
- Pheochromocytoma

Iatrogenic
- Exogenous CO_2 source (e.g. laparoscopy)
- Overwarming
- Neuroleptic Malignant Syndrome

Neurologic
- Meningitis
- Intracranial bleed
- Hypoxic encephalopathy
- Traumatic brain injury

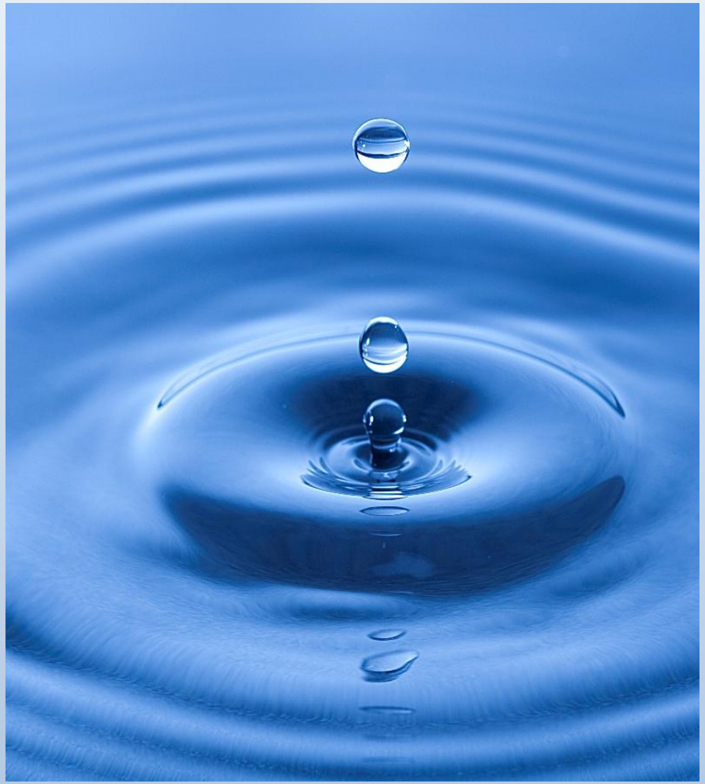
Toxicology
- Radiologic contrast neurotoxicity
- Anticholinergic syndrome
- Cocaine, amphetamine, salicylate toxicity
- Alcohol withdrawal

Room for notes

Real-Time Debriefing after the Critical Event

Potential elements for debriefing just after a perioperative event include (but are not limited to):

1. **W**elfare check:
    - Assessing if team members are ok to continue providing care
2. **A**cute/Short-term corrections:
    - Matters to be addressed before next case?
    - Clinical/patient care needs?
3. **T**eam Reactions and Reflection:
    - Summarize case and listen to team member reactions
    - Plus/Delta: Matters that went well and matters that could be improved
4. **E**ducation:
    - Lessons learned from the event and the debriefing
5. **R**esource Awareness and longer-term needs:
    - Improve awareness of local peer-support and employee assistance resources
    - Assess if any follow-up needed (e.g., safety/quality improvement report)



While a drop of water may seem small in time and space, it can have a substantial ripple effect.

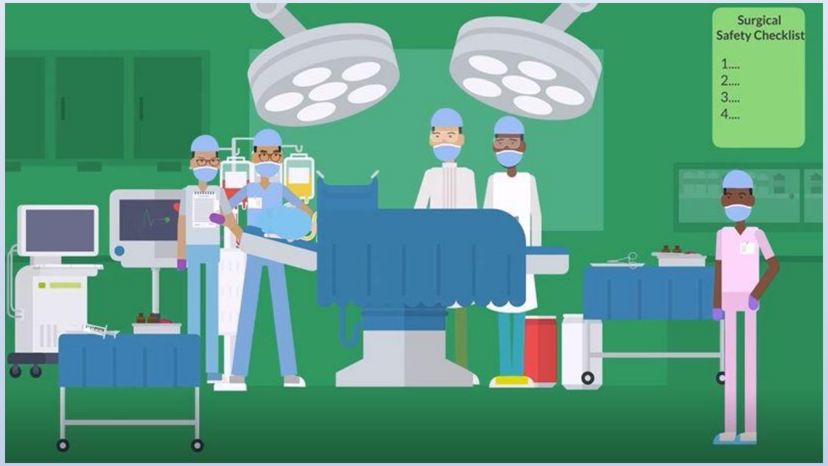
Room for important phone numbers and institution-specific peer-support and/or safety resources

Chen YK, Arriaga AF. Crisis checklists in emergency medicine: another step forward for cognitive aids. BMJ Qual Saf 2021. All reasonable precautions have been taken to verify the information contained in this publication. The responsibility for the interpretation and use of the materials lies with the reader. Image: Restivo D. Water Drop impact on water surface. Available at https://commons.wikimedia.org/wiki/File:Water_drop_impact_on_a_water-surface_-_(5).jpg. Accessed Feb 13, 2021. With permission via Creative Commons CC BY-SA 2.0 License (https://creativecommons.org/licenses/by-sa/2.0/legalcode).

Additional Online Education Material on Realtime Perioperative Critical Event Debriefing

Online-module-style webpage on datadrivendidactics.org dedicated to literature, cognitive aids, and educational videos on realtime perioperative critical event debriefing

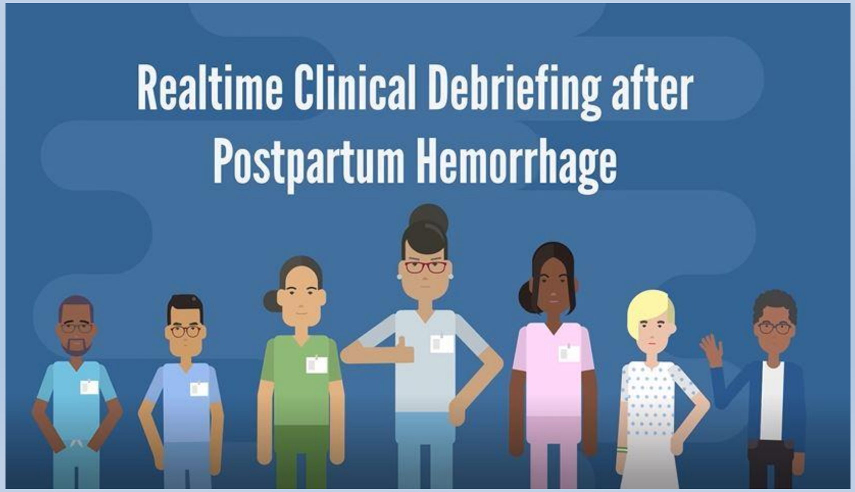
Postpartum Hemorrhage

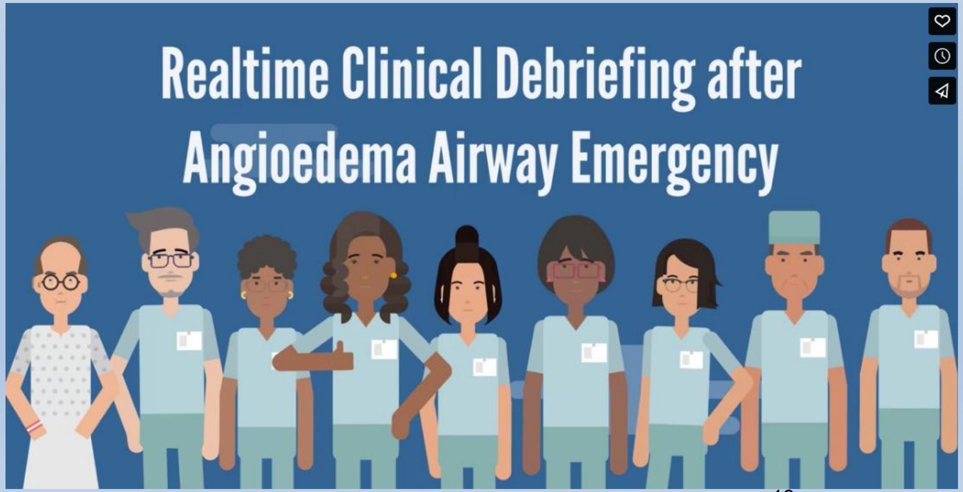


Angioedema Airway Emergency

Angioedema with airway compromise in the emergency department simulation; involves topics from Anatomy & Airway section (difficult airway management, beginning with awake fiberoptic intubation); second video gives practical example of debriefing checklist in use.

Postpartum hemorrhage simulation; includes topics from Obstetrics Section (OB Hemorrhage Crisis Checklist, uterotonics, antifibrinolytics, and other areas); second video gives practical example of debriefing checklist in use.





www.datadrivendidactics.org/debriefing-resources

PBLD Stem Case 3

Room for notes

- A 25-year-old man is in the intensive care unit (ICU) after recovering from carbon monoxide poisoning and sustaining 25% body surface area burns from an apartment fire a few days ago. The surgeon would like to take this patient to the operating room for a debridement and says the team should have blood available in the operating room.

- The anesthesiologist offers the medical student an opportunity to perform the intubation, but first asks the medical student if there are any common anesthesia induction medications that need to be avoided in burn patients. The ICU physician is ordering blood and asks the student: “What is the difference between a type-and-cross and a type-and-screen?” The medical student asks you for help. What would you advise?

Thoracic/Pulmonary

25X

<u>Carbon monoxide (CO) poisoning/carboxyhemoglobinemia</u>: SpO2 falsely elevated relative to SaO2. <u>Methemoglobinemia</u>: SpO2 falsely approaches 85%. → Use Multiwavelength pulse oximeter ("Pulse CO-Oximeter" is Masimo trademark).

- Both increase oxyhemoglobin affinity for O2 → both cause left shift of oxyhemoglobin dissociation curve.
- p50: The PO2 at which hemoglobin is 50% saturated with oxygen.

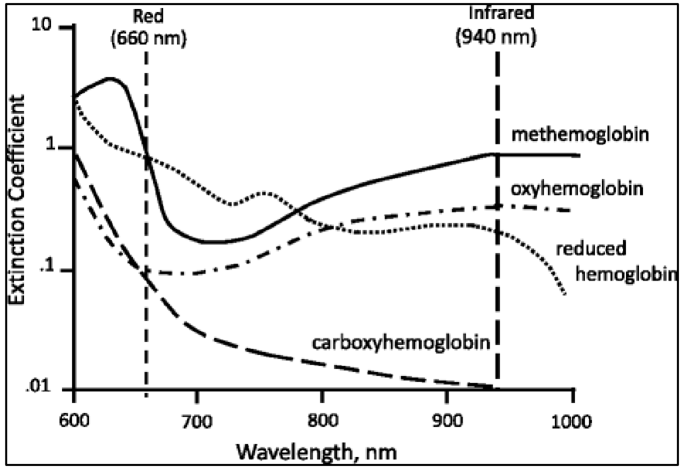
COHb level	Comments/Symptoms (COHb = Carboxyhemoglobin)
<u><</u>10%	Smokers
15-20%	Headaches, dizziness, confusion
>20%	Progression of symptoms: Nausea/vomiting, seizures, myocardial ischemia, organ dysfunction, coma, imminent death (>60-80%)
>25%	Hyperbaric oxygen therapy discussed/considered

<u>Smoking cessation</u>: Optimal time: 8 weeks preop. Some say "increased sputum/reactive airways" in short term after cessation. Many recommend immediate cessation preop regardless. Cessation drops carboxyhemoglobin → oxyhemoglobin dissociation curve shifts back to the right.

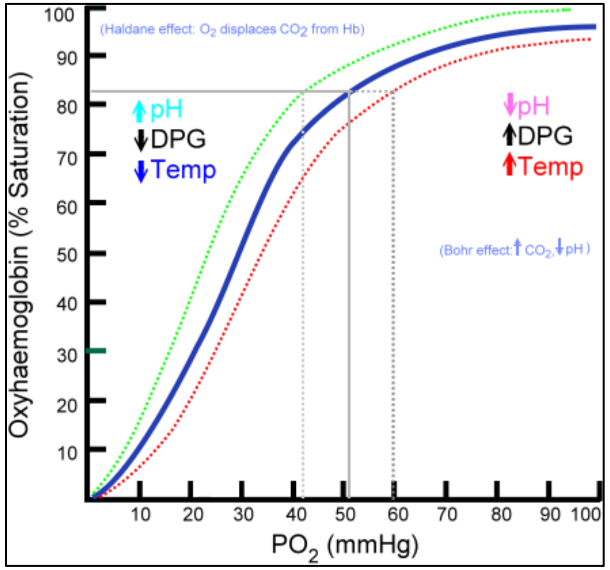
- <u>ASA Statement on Smoking Cessation</u>: "surgery may represent a teachable moment for…smoking cessation…patients should abstain from smoking…both **before** and after surgery."

Kahn Academy video on Haldane and Bohr effect (Dr. Rishi Desai): https://youtu.be/dHi9ctwDUnc

Pulse oximeter typically uses 660 & 940nm



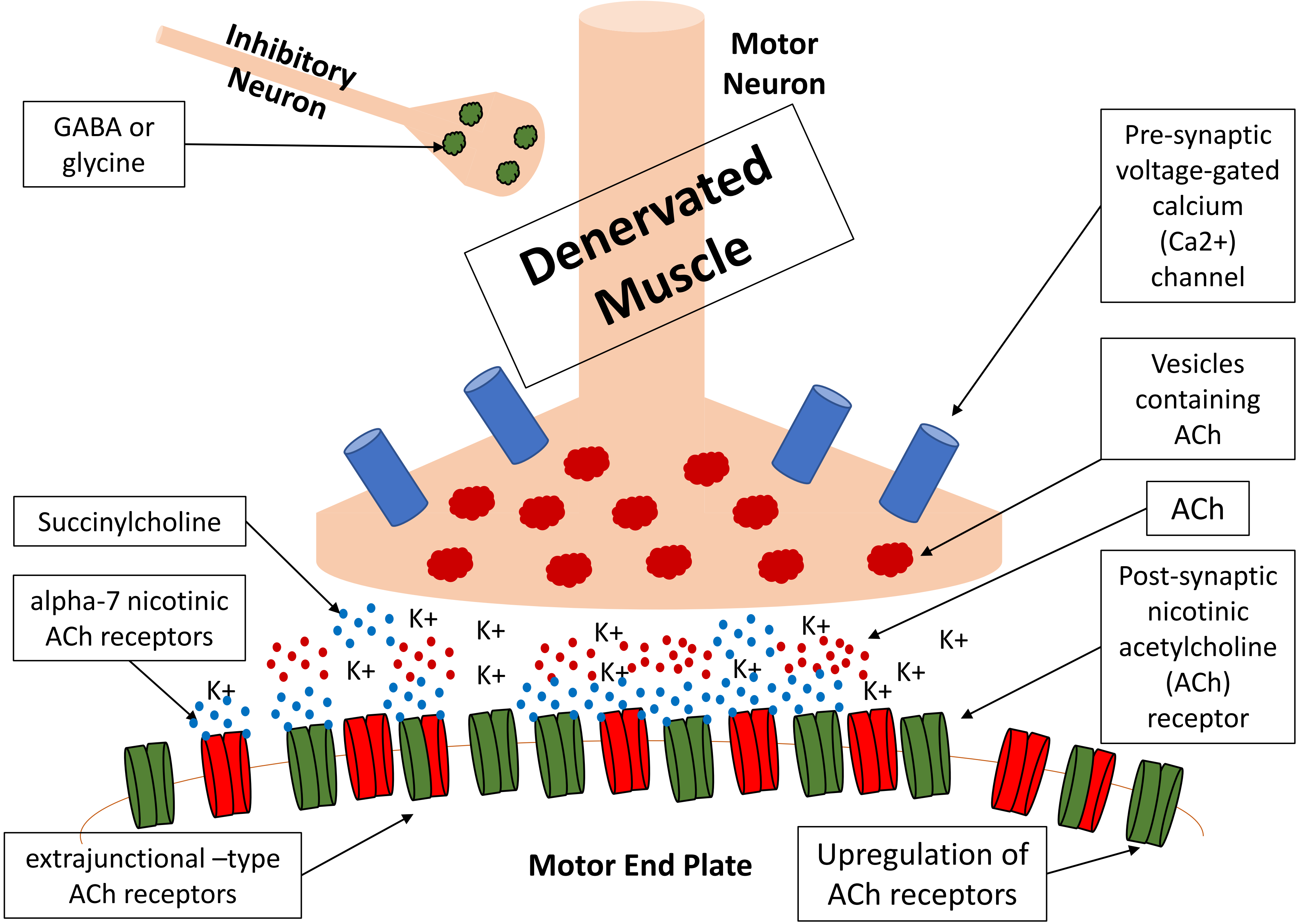
Oxyhemoglobin Dissociation Curve



UptoDate. Strategies to reduce pulmonary complications in adults. // OpenAnesthesia CO Poisoning. // Extinction coefficients image: Jubran A. PMID 26179876. Creative Commons CC-BY-4.0 // Miller Basics 7th Ed, Ch 5. // Miller 9th Ed, Ch 13, 41, 75 // Dissociation Curve: Ratznium/Aaronsharpe. Wikimedia Commons public domain. https://commons.wikimedia.org/wiki/File:Oxyhaemoglobin_dissociation_curve.png // https://www.masimo.com/company/news/news-media/2005/ Accessed 12/18/19 // Barash 8th Ed, Ch 53 // Ferri's Clinical Advisor 2022: Carbon Monoxide Poisoning // ASA Statement on Smoking Cessation.

Room for notes

Upregulation in denervated muscle

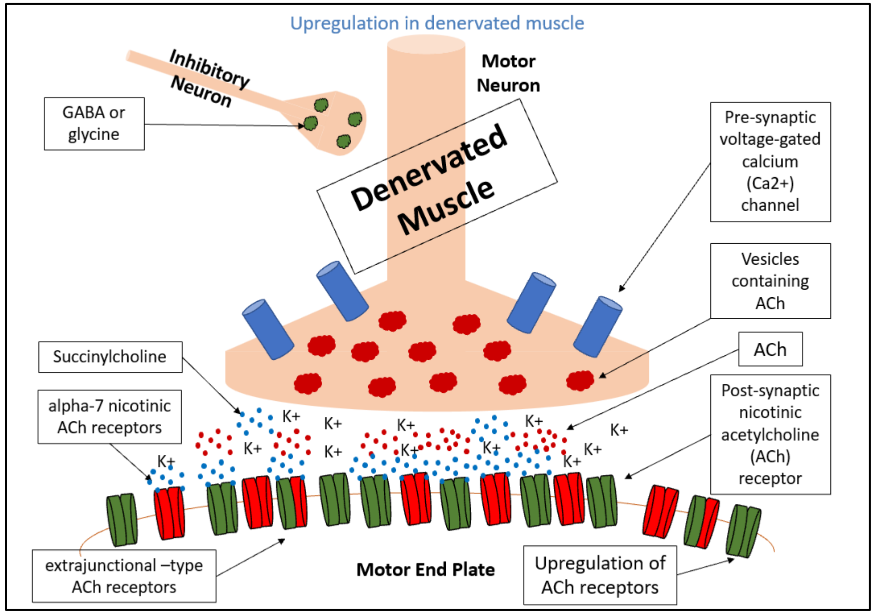


Room for notes

Succinylcholine & Related Topics

Room for notes

Succinylcholine and Denervated Muscle



<u>Recommended high-yield reading</u>:

1. Martyn JAJ. Succinylcholine-induced hyperthermia in acquired pathologic states: etiologic factors and molecular mechanisms. Anesthesiology 2006; 104: 158-69.
2. Miller 9th Ed, Ch 27, pages 794-799 (Pharmacology of Succinylcholine)

<u>Patients particularly susceptible to hyperkalemia from succinylcholine (normal serum potassium increase from Sux: 0.5mEq/dL)</u>:

1. CNS & upper motor neuron lesions (e.g. stroke, tumors/masses), especially if weakness.
2. Demyelinating diseases (MS, Guillain-Barre Syndrome).
3. Many muscular disorders (muscular dystrophy [confounded with risk of MH-like syndrome], myotonic dystrophy).
4. Severe burns or crush injuries (starting 24 hours after the injury and PEAKS 7-10 days after the injury).
5. Prolonged immobility or neuromuscular blockade.
6. Severe metabolic acidosis and hypovolemia.

Upregulation of neuromuscular junction (NMJ) and extrajunctional cholinergic receptors is thought to be the etiology (muscular dystrophy etiology may be rhabdomyolysis).

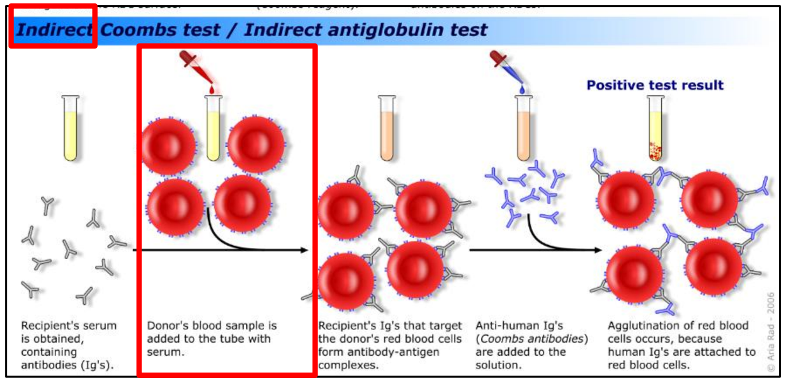
Martyn JAJ et al. Neuromuscular physiology and pharmacology. In Miller's Anesthesia, 9th Ed, Ch 12 // Miller 9th Ed, Ch 27

Transfusions

19X

Room for notes

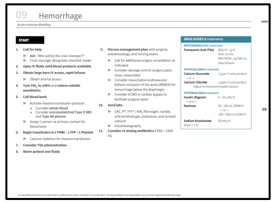
Antibody Screen vs. Crossmatch (both can be done via indirect Coombs test): **Antibody screen:** Recipient's serum mixed with commercially supplied RBCs [known to contain common antigens]. **Crossmatch**: Recipient's serum mixed with Donor RBCs.



Washed, Leukoreduced, Irradiated Blood Products:

- IgA deficiency and transfusion: Pt with anti-IgA antibodies and donor has IgA antigen → severe, often rapid, allergic reaction can occur.
  - Alternative option: **Washed** RBCs "so that all traces of donor IgA have been removed or with blood that lacks the IgA protein."[1]
- **Leukoreduced** blood products lower risk of: febrile reaction; HLA alloimmunization, CMV, transmission of variant Creutzfeld-Jakob disease, and leukocyte-induced immunomodulation. Many institutions implement "universal leukoreduction."[1]
- **Irradiated** cellular products (RBC, platelets, granulocytes – FFP and cryoprecipitate are noncellular and no not need irradiation): Prevents proliferation of donor T-lymphocytes (can cause graft-versus-host disease). Indications include critically ill children, marrow cell transplant recipients, immunodeficient patients and other select indications.[1]
  - *2021 ITE Gaps in Knowledge*: "Gamma radiation of blood is appropriate for immunodeficient patients."

Handout: Hemorrhage Crisis Checklist



Citrate Intoxication & Transfusion: Citrate binds (chelates) calcium and can cause **hypocalcemia** (hypotension, narrow pulse pressure, arrhythmias, confusion, tetany) and coagulopathy (calcium is co-factor in coagulation cascade). **Patients at increased risk**: liver disease/liver transplant status, as well as pediatric patients (reduced citrate metabolism).[1-4]

Upper Figure: Coombs test schematic. Available at https://en.wikipedia.org/wiki/Coombs_test. Available by GNU Free Documentation License & Creative Commons Attribution-Share Alike 3.0 Unported license. // 1. Miller 9th Ed Ch 49 // 2. Miller 9th Ed Ch 47 // 3. Miller 9th Ed Ch 60 // 4. Barash 9th Ed Ch 53

09 Hemorrhage

Acute massive bleeding

INDEX

START

1. **Call for help**
   - **Ask:** *"Who will be the crisis manager?"*
   - Crisis manager designates checklist reader
2. **Open IV fluids until blood products available**
3. **Obtain large bore IV access, rapid infuser**
   - Obtain arterial access
4. **Turn FiO_2 to 100%** and **reduce volatile anesthetics**
5. **Call blood bank**
   - Activate massive transfusion protocol
     - Consider **whole blood**
     - Consider **uncrossmatched Type O RBC and Type AB plasma**
   - Assign 1 person as primary contact for blood bank
6. **Begin transfusion in 1 PRBC : 1 FFP : 1 Platelet**
   - Calcium repletion for massive transfusion
7. **Consider TXA administration**
8. **Warm patient and fluids**
9. **Discuss management plan** with surgical, anesthesiology, and nursing teams
   - Call for additional surgery consultation as indicated
   - Consider damage control surgery (pack, close, resuscitate)
   - Consider resuscitative endovascular balloon occlusion of the aorta (REBOA) for hemorrhage below the diaphragm
   - Consider ECMO or cardiac bypass to facilitate surgical repair
10. **Send labs**
    - CBC, PT / PTT / INR, fibrinogen, lactate, arterial blood gas, potassium, and ionized calcium
    - Viscoelastography
11. **Consider re-dosing antibiotics** if EBL > 1500 mL

DRUG DOSES & treatments

ANTIFIBRINOLYTIC treatment

Tranexamic Acid (TXA)	BOLUS: 1 g IV Over 10 min INFUSION: 1 g/ 500 mL Over 8 hours

HYPOCALCEMIA treatment

Calcium Gluconate	1 g per 3 units product
— or —	
Calcium Chloride	1 g per 5 units product

Adjust to measured ionized calcium

HYPERKALEMIA treatment

Insulin (Regular)	5 - 10 units IV
— and —	
Dextrose	50 - 100 mL D50W IV — or — 250 - 500 mL D10W IV
Sodium bicarbonate (if pH < 7.2)	50 mEq IV

Room for notes

Transfusion Reactions

13X

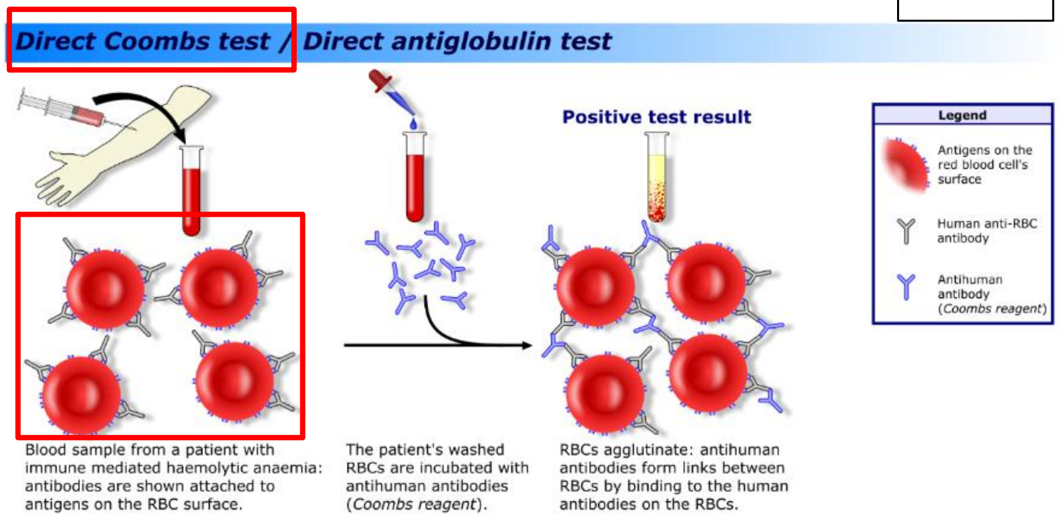
Room for notes

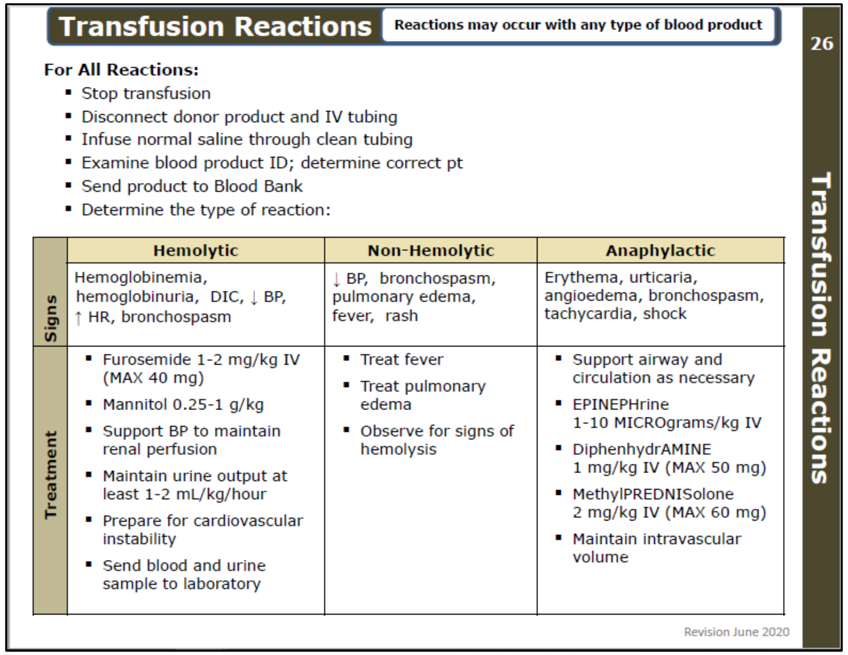
- Mild febrile vs hemolytic reaction: “A **direct antiglobulin test** readily differentiates a hemolytic reaction from a febrile reaction because this test rules out the attachment of an RBC antibody to transfused donor RBCs…No clear consensus exists on whether the transfusion should be terminated when a febrile reaction occurs.” [Miller 9th Ed, Ch49]

- Hemolytic transfusion reaction lab findings: low serum haptoglobin (hemolysis → hemoglobinemia → hemoglobin binds to haptoglobin), elevated indirect bilirubin and lactate dehydrogenase, hemoglobinuria, positive direct Coombs test, possible DIC.

- Delayed hemolytic transfusion reaction: May present 2-21 days after the transfusion (decreased hematocrit, jaundice, hemoglobinuria, and/or impaired renal function).

- Handout: Crisis Checklist for Transfusion Reaction.





Transfusion Reactions — Reactions may occur with any type of blood product — 26

For All Reactions:
- Stop transfusion
- Disconnect donor product and IV tubing
- Infuse normal saline through clean tubing
- Examine blood product ID; determine correct pt
- Send product to Blood Bank
- Determine the type of reaction:

	Hemolytic	Non-Hemolytic	Anaphylactic
Signs	Hemoglobinemia, hemoglobinuria, DIC, ↓ BP, ↑ HR, bronchospasm	↓ BP, bronchospasm, pulmonary edema, fever, rash	Erythema, urticaria, angioedema, bronchospasm, tachycardia, shock
Treatment	▪ Furosemide 1-2 mg/kg IV (MAX 40 mg) ▪ Mannitol 0.25-1 g/kg ▪ Support BP to maintain renal perfusion ▪ Maintain urine output at least 1-2 mL/kg/hour ▪ Prepare for cardiovascular instability ▪ Send blood and urine sample to laboratory	▪ Treat fever ▪ Treat pulmonary edema ▪ Observe for signs of hemolysis	▪ Support airway and circulation as necessary ▪ EPINEPHrine 1-10 MICROgrams/kg IV ▪ DiphenhydrAMINE 1 mg/kg IV (MAX 50 mg) ▪ MethylPREDNISolone 2 mg/kg IV (MAX 60 mg) ▪ Maintain intravascular volume

Transfusion Reactions

Revision June 2020

Society for Pediatric Anesthesia Critical Event Checklists. Revision Packet March 2023. Latest update available at http://www.pedsanesthesia.org // Miller 9th Ed, Ch 49 // Hematology: Basic Principles and Practice 7th Ed, Ch 110. // Rad A. Coombs test schematic. https://en.wikipedia.org/wiki/Coombs_test. Available by GNU Free Documentation License & Creative Commons Attribution-Share Alike 3.0 Unported license. // https://www.ncbi.nlm.nih.gov/books/NBK448158/

Room for notes

PBLD Stem Case 4

- An anesthesiologist is called to the emergency department to evaluate a 3-year-old girl with a sore throat, fever, and inspiratory stridor. She is having some trouble breathing and is sitting in a tripod position. A workup leads to the diagnosis of epiglottitis.

- The medical student just rotated on pediatrics but has never been part of a pediatric airway scenario. The anesthesiologist asks the student if there are any anatomical differences between a pediatric and adult airway. Is epiglottitis an airway emergency? The medical student asks you for help. What would you advise?

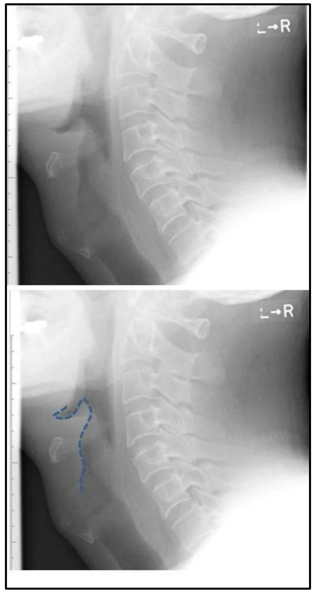
Pediatrics

Room for notes

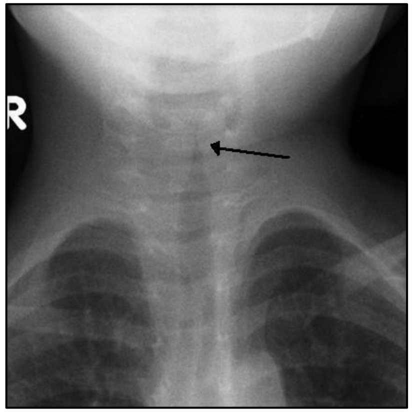
Epiglottitis:

- Potentially life-threatening infection of supraglottic structures. Often caused by Haemophilus influenza B or Group A strep. Rarer in children in areas where H. influenzae vaccination used. Severe sore throat, stridor, drooling, patient sitting in tripod position. Induction: airway manipulation in O.R. with monitors on and surgeon present; maintain spontaneous ventilation (inhalational induction), avoid paralytics.
- Croup (laryngotracheo-bronchitis) is often less urgent, associated with barking cough, often caused by parainfluenza virus.
- Other diagnoses that could have a similar presentation include: retropharyngeal abscess, foreign body aspiration.

Epiglottitis:
"Thumbprint sign"



Croup: "Steeple sign"



Adult vs. Pediatric Normal Airway Anatomy:

- Pediatric airway: larynx/glottis higher in neck (closer to C3 than C5 [adults]). Some (controversial) say narrowest point of airway is cricoid cartilage (until age 5), as opposed to glottic opening (adults). Large tongue/occiput and omega-shaped epiglottis.

Grover C. NEJM 2011 PMID 21812674 // Epiglottitis image: https://commons.wikimedia.org/wiki/File:Compare_epiglottis.jpg; CC BY-SA 3.0, via Wikimedia Commons // Lee FE-H. Murray and Nadel's textbook of Emergency Medicine. 2016 // Croup image: https://commons.wikimedia.org/wiki/File:Croup_steeple_sign.jpg, CC BY-SA 3.0, via Wikimedia Commons // Miller 9th Ed Ch 77 // Barash 8th Ed Ch 43

PBLD Stem Case 5

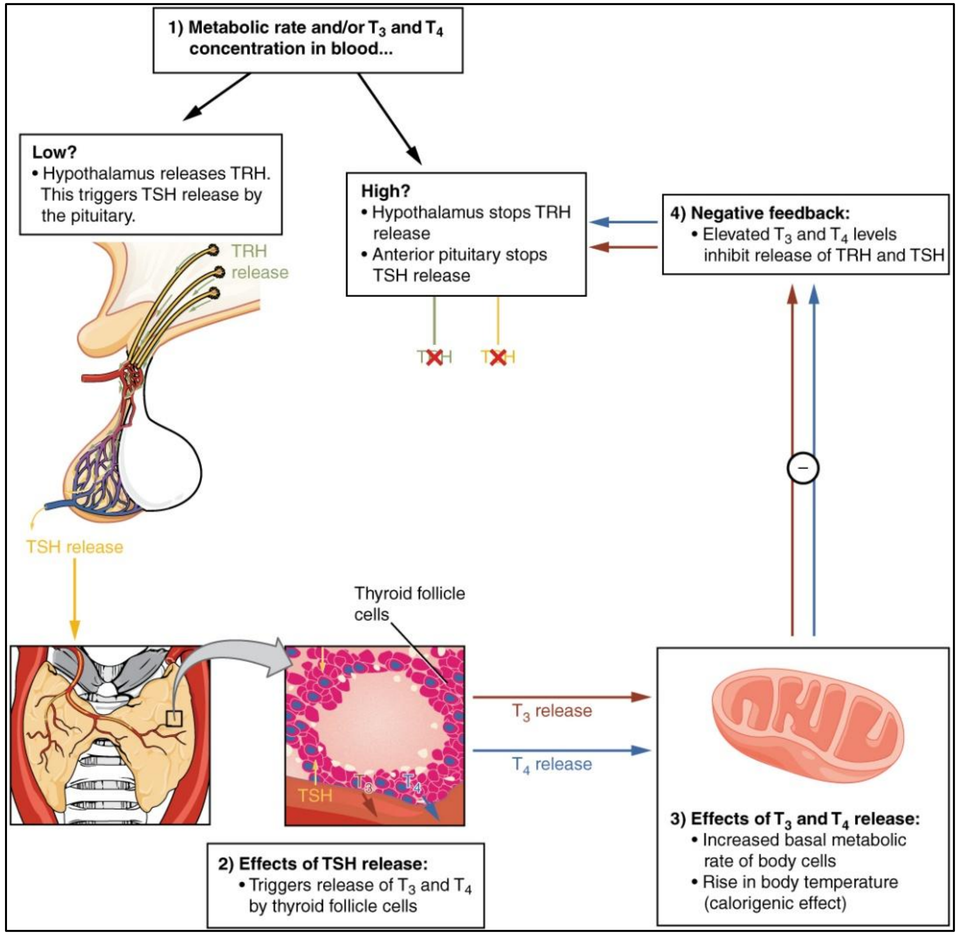
- A 71-year-old woman presents for a partial thyroidectomy to remove a thyroid nodule causing hyperthyroidism (toxic nodular hyperthyroidism). She needed to see both her primary care doctor and an endocrinologist for medical control of symptoms before presenting for the procedure.

- The medical student on the case learned about thyroid physiology during the first year of medical school but is synthesizing this all now in terms of anesthesia implications. The anesthesiologist asks the student:
  - “Why did this patient need to get medical control of symptoms first? What are the dangers of anesthesia in a patient with uncontrolled hyperthyroidism?”

Thyroid

Room for notes

Thyroid Hormone Homeostasis



Serum Thyroid Function Tests in Clinical Conditions*[1-9]

TSH	Free T4	T3	Interpretation
Low	High/ Normal	High	Hyperthyroidism (Ddx includes Graves' disease, iodine or thyroid hormone excess, toxic nodular hyperthyroidism, destructive thyroiditis w/thyroid hormone release)
Normal/ High	High	High	TSH-mediated hyperthyroidism (such as TSH-secreting pituitary adenoma), thyroid hormone resistance
High	Low	Low/ Normal	Primary Hypothyroidism (e.g., Hashimoto's thyroiditis)
Low/ Normal **	Low	Low/ Normal	DDx includes Central/Secondary hypothyroidism (e.g., anterior pituitary dysfunction, hypothalamic disease)

Terminology:[10]
- T_4 (aka thyroxine): prohormone made by thyroid gland.
- T_3: hormone produced both directly by thyroid gland and indirectly via enzymatic deiodination of T_4.
- "Many investigators believe that all effects of thyroid hormones are mediated by T3 [&] T4 functions only as a prohormone."

Additional references for table "Serum Thyroid Function Tests in Clinical Conditions": 1. UpToDate: "Laboratory assessment of thyroid function" // 2. Stoelting 8th Ed Ch 22 // 3. Harrison Principles of Internal Medicine 21st Ed Ch 383 & 384 // 4. UpToDate "Pathogenesis of Graves' Disease" // 5. UpToDate "Pathogenesis of Hashimoto's thyroiditis (chronic autoimmune thyroiditis)" // 6. UpToDate "Disorders that cause hypothyroidism" // 7. UpToDate "Central hypothyroidism" // 8. UpToDate "Drug interactions with thyroid hormones" // 9. UpToDate "Disorders that cause hypothyroidism" //10. Miller 9th Ed Ch 32

* Complex algorithms exist for thyroid dysfunction workup. This table is intended as a referenced synopsis and not a comprehensive guide. **TSH level could be slightly high in some instances of central hypothyroidism (e.g., biologically inactive TSH). Graves' Disease: autoimmune disease due to thyroid-stimulating antibodies that bind to TSH receptors expressed primarily on the thyroid gland. Hashimoto's thyroiditis: chronic autoimmune thyroiditis; thyroid gland may have goitrous enlargement. Image: OpenStax College, CC BY 3.0 via Wikimedia Commons https://commons.wikimedia.org/wiki/File:1813_A_Classic_Negative_Feedback_Loop.jpg

Hyperthyroidism

Room for notes

- Thyrotoxicosis: A condition characterized by clinical manifestations of thyroid hormone excess.[5,7]
- Thyroid Storm: Rare condition characterized by severe clinical manifestations of thyrotoxicosis.[5]

Hyperthyroidism[1-6]	
Clinical manifestations can include:	• Tachycardia, arrhythmias, palpitations, tremors, weight loss, diarrhea; proptosis (in Graves' Disease). • *Thyroid Storm*: progressively severe symptoms, may also include hyperthermia, severe arrythmia, hypotension, CHF, mood disorders, altered mental status, coma.
Perioperative Treatment considerations (goal euthyroid before elective procedures):	
(1) Thionamides (e.g., propylthiouracil [PTU], methimazole)	PTU inhibits conversion of T4 to T3. Given ideally for at least several weeks preop (they decrease de novo thyroid hormone synthesis within hours, but do not impact release of preformed thyroid hormone). Note: agranulocytosis is rare but feared side effect.
(2) Beta-blockers	Propranolol inhibits conversion of T4 to T3. Can treat tachydysrhythmias and rate control.
(3) Iodine	Wolff-Chaikoff effect: Large doses of iodine can transiently inhibit organification of iodine in the thyroid gland. *Used cautiously* or after thionamides to prevent iodine from being used as substrate, particularly in patients with toxic adenoma or toxic multinodular goiter.
(4) Glucocorticoids	Reduces T4 to T3 conversion; may also treat underlying autoimmune process if present.
(5) Other medications	*Cholestyramine* (bile acid sequestrant; interferes w/enterohepatic circulation & recycling of thyroid hormone); *Plasmapheresis* (can remove cytokines, antibodies, & thyroid hormones); *Lithium* (blocks thyroid hormone release, but carries renal, neurologic, & other side effects).
(5) Other intraoperative	Treatment of hyperthermia if thyroid storm (e.g., cooling blankets, acetaminophen); fluid resuscitation & electrolyte repletion as needed.

Refs: 1. Miller 9th Ed Ch 31 // 2. Miller 9th Ed Ch 32 // 3. Steolting 8th Ed Ch 22 // 4. Anesthesia and Uncommon Disease 6th Ed Ch 13 // 5. UpToDate "Thyroid Storm" // 6. UpToDate "Anesthesia for patients with thyroid disease and for patients who undergo thyroid or parathyroid surgery" // 7. Health Harvard Dictionary (https://www.health.harvard.edu/q-through-z#T-terms)

Where to learn more

www.datadrivendidactics.org

End.
Thank you!

Room for notes