McMaster University

Michael G. DeGroote SCHOOL OF MEDICINE

Anesthesia:

A Clerkship Pocket Guide

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Anesthesia: A Clerkship Pocket Guide

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GLOBAL OBJECTIVES:

- To create a free, peer-reviewed practical resource for learners that is both physically accessible in the OR and in hospital, and educationally-appropriate for a clerk's background level of knowledge and experience.
- To cover the required McMaster core anesthesia clerkship learning objectives and Essential Clinical Encounter (ECE) topics so that students can review concepts and questions that may arise during the rotation.
- To provide a sufficient scope of knowledge that clerks may integrate information learned from this core to other specialties (internal medicine, emergency medicine, critical care medicine, OBGYN, family medicine, etc.).
- To encourage a better understanding of the pharmacology behind common drugs encountered in anesthesia including their indications, mechanism of action, considerations for usage, and effects.

HOW TO USE THIS RESOURCE

This resource is grounded in the McMaster core anesthesia clerkship learning objectives and Essential Clinical Encounters (ECEs; a list of high-priority topics and probing questions that students should be exposed to longitudinally during their clerkship).

We suggest using this pocket guide as an accessible adjunct to your clerkship rotation. It cannot substitute for your time in the OR with an anesthesiologist, which will provide invaluable experiential learning, or the required modules, tutorials, and simulation activities.

This resource does not attempt to contain the depth of knowledge required to gain a comprehensive understanding of any topic covered. If you are interested in learning more about a particular topic, references are provided at the end of each section.

Additionally, if something here differs from the practice by the staff in front of you, consider that many practices in all areas of medicine can vary by hospital and by physician — anesthesia is no different. Being curious about the nuances can lead to valuable discussions and learning opportunities.

We sincerely hope you enjoy and learn as much as possible from your anesthesia clerkship rotation!

If you have any suggestions or comments, please email **anesthesiacpg@gmail.com**; we would love to hear your thoughts and feedback!

Disclaimer

Though this resource has been reviewed to the best of our ability, we fully acknowledge the rapidly changing nature of medicine as well as human error. The scope of what this resource can offer is of a general nature only. Those associated with creating this resource are not responsible for errors or omissions or for any consequences which may arise from the use of this resource.

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Pre-operative assessment

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Knowledge-based objectives:
- *Describe the role of the preoperative anesthetic assessment with regards to optimizing patient risk.*
- *Explain the presentation and management of malignant hyperthermia as an example of the hypermetabolic state.*
- *Explain the presentation and management of pseudocholinesterase deficiency (plasma cholinesterase) as an example of a pharmacogenetic disease.*

Essential Clinical Encounters objectives:
- *List 3 comorbidities that may be more commonly seen in the obese patient.*
- *How can OSA impact a patient's disposition post-operatively? Think of strategies to minimize OSA related complications post-operatively.*
- *How might a patient's hypoglycemic therapy may need to be adjusted perioperatively?*
- *For a patient with COPD/asthma, think of strategies to prevent bronchospasm perioperatively.*
- *Describe the components of a pre-anesthestic airway exam.*
- *Describe the Mallampati classification system.*
- *Describe the ASA classification system.*

Skills objectives:
- *Assess a patient who has an ASA class I or II classification with regards to their readiness for anesthesia by taking an appropriate history and performing a relevant physical examination.*
- *Assess the patient's airway for ease of mask ventilation, SGA insertion, or ETT.*

GOALS OF PRE-OP ASSESSMENT

Identify and quantify concerns to adapt your anesthetic management:

- Identify CC/HPI and operation
- Identify pre-op conditions/risk factors
- Quantify and characterize conditions/risk factors with hx and appropriate investigations
- Optimize pt if possible
- Adapt anesthetic technique to promote pt safety and stability throughout perioperative period (e.g. general vs regional anesthetic, ETT vs SGA, RSI, monitoring, drug properties)
- Advanced care planning where appropriate (i.e. medical directives)
- Post-operative disposition plan (i.e. home / wards / step-down unit / ICU)

INVESTIGATIONS AND OPTIMIZATION

- May be ordered in pre-op to assess pt condition and potential ways to optimize before surgery. Labs can be redone just prior to surgery if indicated.
- Always consider if pre-op testing is truly beneficial to pt care before ordering, especially for asymptomatic pts undergoing low-risk surgery.
- See **https://choosingwiselycanada.org/anesthesiology** for details.

Investigations and indications for pre-optimization

Investigation	Indications
CBC	• Major surgery requiring group & screen or match • Malignancy • Chronic CV, respiratory, renal, hepatic disease • Suspected or known anemia or coagulopathy • Pt <1y/o
INR/PTT	• Anticoagulation therapy • Suspected or known coagulopathy • Hepatic disease
Lytes/creatinine	• Therapies affecting lytes (e.g. diuretics) • HTN • Diabetes • Renal, adrenal, or pituitary disease
Fasting glucose	• Diabetes
β-HCG	• Potentially pregnant women
ECG/Echo	• Suspected or known CAD, arrhythmias, PVD, other CV or structural disease; valvular disease or heart failure • For asymptomatic pts with clinical risk factors having intermediate/high-risk surgeries
CXR	• Part of oncological workup/surgery • Acute/chronic cardiorespiratory disease if it will change management

IMMEDIATE PRE-OP ASSESSMENT

- Pts sometimes have a pre-op consult; can tailor pre-op assessment to most important issues.

Pre-operative assessment questions

General	• **ID** (age/sex) • **Procedure** • **ASA classification** • **Allergies** • **Medications** • **NPO status** • **Weight** (for dosing, especially for pediatric pts)
PMHx	• **Surgical/anesthetic Hx**: PONV, difficult intubation, post-op delirium • **CNS**: Confusion/delirium, seizures, CVA/TIA, ↑ ICP, spinal cord injury, • anxiety, MS, migraines • **CVS**: HTN, dyslipidemia, CHF, MI, CAD, pacemaker, valvular disease, dysrhythmia, exercise tolerance • **RESP**: Asthma, COPD, recent URTI, OSA, pulm HTN • **GI**: GERD, hepatic disease, bowel obstruction • **RENAL**: Renal insufficiency, dialysis • **HEME**: Anemia, coagulopathies, DVT/PE, transfusion hx • **MSK**: Arthritis, disease/trauma/radiation of cervical spine, myopathy, chronic pain • **ENDO**: DM, thyroid disease, adrenal suppression • **Soc Hx**: Pregnancy, EtOH/smoking/recreational drug hx
FHx	• Malignant hyperthermia • Pseudocholinesterase deficiency
Physical exam	• Mallampati classification • **Oropharynx & airway assessment**: inter-incisor gap, neck extension, thyromental distance, mandibular protrusion, upper lip bite test • **Assess for difficult BMV:** BONES (beard, obesity, no teeth, elderly, snoring/sleep apnea) • Focused cardiac/resp/neuro exam, vitals • Existing sensory/motor deficits • Examine back for spinal/epidural if indicated
Other	• **Existing dentition** (loose, chipped, caps, dentures) – inform pt of risk of damage

NPO guidelines
8h: Solid/fatty foods
6h: Formula/non-human milk/light meal
4h: Breastmilk
2h: Clear fluids

Previous surgical/anesthetic/family Hx

✷ PMHx of difficult BMV/intubation is one of the best predictors for future attempts. Check the previous anesthetic records and make a note for future reference.

ASA score

1	Healthy	
2	Mild systemic disease	e.g. Well-controlled HTN, smoker, social drinker
3	Severe systemic disease with functional limitation	e.g. Poorly-controlled HTN w renal insufficiency, controlled COPD, fatty liver disease severe obesity
4	Incapacitating disease with constant threat to life	e.g. HTN w renal failure on dialysis, poorly-controlled COPD, cirrhosis w varices
5	Moribund, not expected to survive >24h without surgery	e.g. Acute liver failure, ruptured AAA, massive trauma/hemorrhage
6	Declared brain dead	Organ donor awaiting transplant

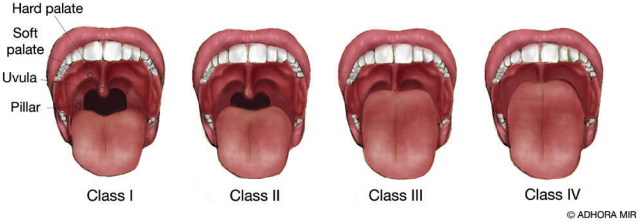
✶ E added if emergent surgery (e.g. ASA 3E)

MALLAMPATI CLASSIFICATION

Mallampati classification: what can be visualized?

1	2	3	4
Faucial pillars, soft palate, entire uvula	Faucial pillars, soft palate partial uvula	Soft palate only	Hard palate only

Figure 1: Mallampati classification



OBSTRUCTIVE SLEEP APNEA (OSA)

Definition: Decreased or complete cessation of breathing during sleep. Sleep study showing apnea-hypopnea index (AHI) ≥15/hr, or ≥5 with symptoms or CV comorbidities.

Signs/symptoms: ↓SpO2, intermittent hypoxia/hypercapnia.

Complications/comorbidities: Systemic/pulmonary HTN, LVH, arrhythmias, cognitive impairment, increased susceptibility to respiratory depression, obesity hypoventilation syndrome.

Risk factors: **STOP-BANG** (≥3 = high likelihood of OSA)
- **S**noring
- **T**ired (daytime somnolence)
- **O**bserved periods of apnea
- **P**ressure (HTN)
- **B**MI > 35
- **A**ge > 50
- **N**eck circumference > 40cm
- **G**ender (male)

Pre/intra-operative management: Supplemental O2 and adequate pre-oxygenation, CPAP/BiPAP therapy preoperatively (ask pt to bring their own machine), opioid-sparing multimodal/regional techniques, reverse Trendelenburg positioning, extubation when awake.

Post-operative management: Careful monitoring for apnea and cardiorespiratory complications (may require continuous oximetry monitoring overnight before discharge), supplemental O2, CPAP/BiPAP therapy, semi-upright or lateral position, opioid-sparing analgesia.

SEVERE OBESITY

Definition: BMI ≥35

Physiological changes: ↑CO, ↑GFR, ↑total body weight/volume, ↑metabolic rate, ↑oxygen demands.

Complications: Difficult BMV, rapid desaturation on induction, ↓ lung volumes, ↓ chest wall/diaphragm compliance (esp with Trendelenburg, pneumoperitoneum), obesity hypoventilation syndrome, OSA.

Pre/intra-operative management: Continue CPAP/BiPAP if used at home, consider inherent risk of proposed surgery and assess cardiorespiratory status with appropriate investigations, avoid respiratory depressants, be aware of lipophilic drugs that may have delayed clearance in obese people (e.g. desflurane vs sevoflurane).

Post-operative management: Extubate when awake, optimal positioning, CPAP if used at home, careful monitoring for respiratory complications.

DIABETES MELLITUS

Physiological changes: Autonomic dysfunction (orthostatic HTN, hypothermia), HTN, CAD, PVD, CKD, ↓ gastric motility, stiff joint syndrome, hypoglycemia.

Complications: Silent MI, poorer wound healing, autonomic/peripheral neuropathy, stiff joint syndrome, "full" stomach.

Pre-operative management: Take comprehensive hx (type I or II, glucose control, insulin-dependence, evidence of end-organ/autonomic dysfunction, airway exam, meds),

measure glucose frequently, insulin infusion for more aggressive glycemic control, consider RSI if gastroparesis present, hold hypoglycemic agents while NPO and may need to reduce dose the night before procedure.

Post-operative management: Measure glucose frequently, monitor for post-op complications associated with end-organ damage, ensure basal insulin levels, dextrose infusion if hypoglycemic.

COPD

Physiological changes: Obstructive lung disease, ↑compliance, ↑mucus secretions, V/Q mismatch, alveolar hypoventilation, ↓ gas transfer, pulmonary HTN.

Complications: Bronchospasm, laryngospasm, hemodynamic instability, baro/

volutrauma, auto-PEEP, post-op complications (e.g. infections, respiratory failure).

Pre/intra-operative management: Assess exercise tolerance and severity of disease, counsel on smoking cessation perioperatively, continue puffers until day of surgery, consider regional anesthesia, obtain baseline room air ABG pre-operatively, consider art line (serial ABGs for high-risk pts; comparison to baseline may help guide timing for extubation), positive pressure during preoxygenation.

Post-operative management: Respiratory support and close monitoring, suctioning and physiotherapy to avoid sputum plugging, high risk pts should be monitored with ABGs and compared to baseline.

POST-OPERATIVE NAUSEA/VOMITING

Chemoreceptor trigger zone (CTZ): Area of the brainstem which is stimulated through opioid, serotonin (5HT3), histamine, dopamine, and muscarinic ACh receptors. Adequate stimulation will communicate signaling to initiate vomiting.

Simplified Apfel score for PONV:
- Female
- Hx of PONV or motion sickness
- Non-smoker
- Post-operative opioids

Other risk factors:
- Younger age
- Volatile anesthetics
- Surgery >2h
- Pregnancy
- Abdomen, breast, ENT/ophthalmic, neurosurgery

Score from 0-4 (% incidence of PONV):
0 – 10%
1 – 20%
2 – 40%
3 - 60%
4 - 80%

PONV prophylaxis usually involves 1-2 drugs:
- Ondansetron
- Dexamethasone
- Dimenhydrinate
- Haloperidol

(*See Quick Drug Reference: Post-operative nausea/vomiting.*)

Other preventative strategies:
- Multimodal analgesic approach to minimize opioid use
- Regional/local anesthesia

- Use propofol for induction and maintenance of general anesthesia rather than volatile anesthestics
- Euvolemia (adequate hydration)
- Metoclopramide/H2 receptor antagonist/PPI

PACU HANDOVER

General	• ID (age / sex) • Procedure and type of anesthetic • Most responsible physician • Allergies • Significant PMHx/medications
Anesthetics	• Anesthetics given • NMBA reversed? (Y / N) • Intubation (easy / hard, # of attempts)
Other	• Significant intra-op events • Abx given/time • Fluids (in: pRBC, crystalloids; out: UOP, EBL) • Foley? (Y / N) • Lines (gauge / location) • Post-op pain management

COMPLICATIONS & EMERGENCIES

MALIGNANT HYPERTHERMIA

Definition: A rare autosomal dominant genetic condition that can be triggered by certain anesthetic agents leading to ↑↑ Ca2+ release, sustained muscle contraction, and hypermetabolic crisis.

Triggers: Succinylcholine, volatile agents (except N2O).

Signs/symptoms:
Early: ↑ ETCO2, ↓ SpO2, ↑ HR, ↑ RR, masseter spasm
Late: HTN, total body rigidity, severe lactic acidosis, hyperthermia, rhabdomyolysis.

Complications: Hyperthermia, hyperK+, arrhythmias, DIC, AKI, cerebral edema, compartment syndrome, cardiac arrest, death.

DDx: Light anesthesia, insufflation with CO2, thyroid storm, sepsis, pheochromocytoma, serotonin-syndrome, neuroleptic malignant syndrome.

Risk factors: F/Hx of MH, unexplained fever/cramps/weakness, myopathies.

Prevention: Identify at-risk pts through F/Hx, book as first case of the day, replace circuit/CO2 absorbers, remove vaporizers and flush machine, remove succinylcholine vials from cart, TIVA, carefully monitor ETCO2 and temperature, have dantrolene available.

Management: Stop succinylcholine/volatile agents, 100% FiO2, push dantrolene, treat K+ abnormalities and acidosis, increase minute ventilation, cool pt, supportive care; consider muscle biopsy/genetic testing post-op.

PSEUDOCHOLINESTERASE DEFICIENCY

Definition: An autosomal recessive genetic condition in which there is a deficiency in the enzyme that breaks down certain anesthetic drugs.

Triggers: Succinylcholine, mivacurium.

Signs/symptoms: Prolonged respiratory paralysis/apnea.

Complications: Prolonged mechanical ventilation, respiratory failure if extubated early.

DDx: Diaphragmatic paralysis, hypoK+, hyperMg2+.

Risk factors: Use of succinylcholine, F/Hx of pseudocholinesterase deficiency or unexplained extended paralysis under general anesthesia.

Prevention: Identify at-risk pt and avoid triggering agents.

Management: Continue mechanical ventilation and hemodynamic support until paralysis self-resolves; record condition in pt chart.

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Orientation to the monitors and anesthetic machine

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Knowledge-based objectives:
- *Describe at least 3 systems (i.e. circuits) for delivering oxygen to patients.*
- *Explain common mechanical ventilation parameters (volume control and pressure control ventilation, respiratory rate, tidal volume, pressure and PEEP).*
- *Describe how we measure patient ventilation and oxygenation and how to determine if they are adequate.*
- *Demonstrate appropriate use of the circuit and ventilator with minimal assistance.*

Essential Clinical Encounters objectives:
- *List 5 anesthetic considerations for laparoscopic surgery.*
- *Why can end tidal CO2 increase during laparoscopic surgery?*
- *If a patient's condition raises concerns of cardiovascular instability intraoperatively, how could you adapt your technique in terms of monitoring?*
- *How would you detect and manage an intraoperative myocardial infarction?*
- *According to the Canadian Anesthesiologists' Society, which monitors must be continuously used intraoperatively?*
- *According to the Canadian Anesthesiologists' Society, which monitors must be immediately available if needed?*

Skills objectives:
- *Place appropriate monitoring devices prior to induction (ECG, NIBP, SpO2).*

CAS STANDARD MONITORING GUIDELINES

Required continuously:	Available for use without delay:
Oxygenation 1. Pulse oximeter **Ventilation** 2. ETCO2 capnography 3. Agent-specific anesthetic gas monitor **Circulation** 4. ECG 5. NIBP (q3-5m)	• Temperature probe • Peripheral nerve stimulator • Stethoscope **Available without undue delay:** • Spirometer for tidal volume • Manometer for ETT cuff pressure

PULSE OXIMETRY

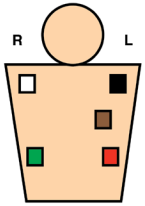
- Provides an estimate of arterial oxygenation expressed as percent saturation
- Tracing can be used to assess HR, perfusion status, volume status (plethysmography variation index)
- **Falsely-low SpO2**: Methemoglobin (SpO2 approaches 85%; may be falsely higher or lower), nail polish, shivering, ↓ perfusion, misplaced sensor, IV dyes such as methylene blue.
- **No effect on SpO2**: HbF, HbS, bilirubin.
- **Falsely-high SpO2**: Carboxyhemoglobin, red nail polish.

NON-INVASIVE BP

- May be used with invasive monitoring techniques (e.g.art-line)

ECG

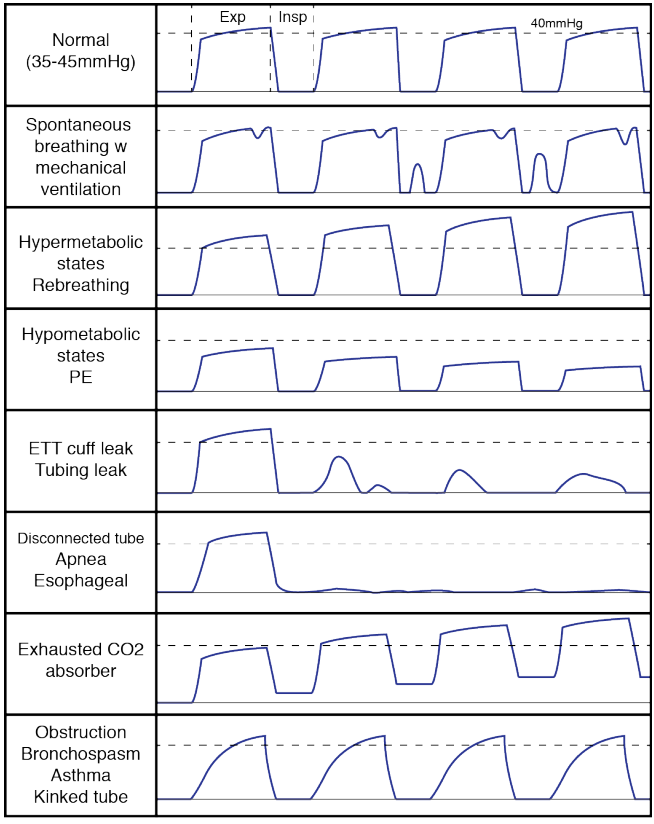
- Usually 3 or 5 electrodes; defaults to monitoring lead II
- 3 electrode: “White on the right, smoke (black) over fire (red).”
- 5 electrode: “Snow (white) over trees (green); chocolate (brown) close to the heart.”
  - White = R arm
  - Black = L arm
  - Red = L leg
  - Green = R leg
  - Brown = V5



CAPNOGRAPHY

- Waveform and numerical measurement of end-tidal concentration of CO2.
- ETCO2 is ~2-5mmHg lower than PaCO2 in healthy lungs (normal PaCO2 is 35-45mmHg). This gradient is due to mixing with anatomic, alveolar, or mechanical dead space air; the gradient is increased in diseased lungs and in cases of poor pulmonary perfusion.
- **Reasons for increased ETCO2**: Hypermetabolic states (e.g. MH, sepsis), sudden release of tourniquet, insufflation with CO2 (e.g. laparoscopic surgery), hypoventilation, rebreathing, saturated CO2 absorber.
- **Reasons for decreased ETCO2:** Hypometabolic states (e.g. hypothermia), decreased pulmonary blood flow (e.g. PE), hyperventilation, tubing leakage/kink, low cardiac output states.

Figure 2: Examples of capnography waveforms



BASICS OF MECHANICAL VENTILATION

(See also Airway management, intubation, and emergencies.)
Pressure control: Set inspiratory pressure applied per breath.
Volume control: Set tidal volume per breath.
Trigger: What initiates the breath (i.e. pressure vs flow)?
Limit: What determines the volume given (i.e. patient vs ventilator)?
Cycle: What determines the end of a breath (i.e. flow vs time)?
Tidal volume: The volume of air expired in one breath (typically ~6mL/kg).
Minute ventilation: The total volume of air inhaled or exhaled in one minute.
Tidal volume x RR.
I:E ratio: Ratio of time spent in inspiratory phase:expiratory phase. Normally 1:2 but can be decreased (e.g. 1:3) for pts with obstructive lung disease to reduce risk of hyperinflation.
Positive End-Expiratory Pressure (PEEP): Maintains patency of small airways with positive pressure at the end of exhalation; ↓ preload, ↑ ICP.
Compliance: ΔVolume/ΔPressure

BASIC VENTILATION SETTINGS

Volume Control (VC): Set V_T and RR; machine delivers this minute ventilation at a constant flow rate.
Advantages: Delivers a guaranteed tidal volume.
Disadvantages: Associated with higher inspiratory pressures and barotrauma

Pressure-Control Ventilation (PCV): Set Inspiratory pressure and RR; machine delivers this pressure for a specified inspiratory time.
Advantages: Associated with lower inspiratory pressures and lowers barotrauma risk.
Disadvantages: Tidal volume varies with changing lung compliance (e.g. insufflation, patient positioning, changes in muscle relaxation).

Pressure Control Ventilation with Volume Guarantee (PCV-VG): Machine delivers set tidal volume at minimum required inspiratory pressure and is adjusted breath-by-breath. Guarantees a minimum minute ventilation while minimizing risk of barotrauma. Common ventilation mode intraoperatively.

Synchronized Intermittent Mandatory Ventilation (SIMV): Machine synchronizes with pt's breathing pattern and delivers ventilator breaths between pt-triggered breaths to achieve a minimum minute ventilation. Ventilator breaths can be delivered with volume or pressure control.
Advantages: Pt can breathe spontaneously, allows gradual weaning from ventilation.
Disadvantages: Fatigue, chest wall/MSK disorders that compromise inspiratory strength, L ventricular dysfunction, ventilator dyssynchrony.

Pressure-Support Ventilation (PSV): Ventilator supports each pt-triggered breath with set pressure; machine does not initiate breaths (prolonged periods of apnea will lead trigger safety-net ventilator-initiated breath). Can be used with CPAP for improved alveolar recruitment.
Advantages: Can be used for pts who can spontaneously breathe but require intubation (e.g. altered mental status, intra-op procedures where mechanical ventilation is not required), prior to extubation/transitioning from mechanical ventilation to spontaneous ventilation.
Disadvantages: Not appropriate for unstable/fatigued/apneic pts.

COMPLICATIONS & EMERGENCIES

AUTO-PEEP/DYNAMIC HYPERINFLATION

Definition: Occurs when the lungs do not fully deflate and leads to air-trapping; this increases the dead space ventilation and V/Q mismatch.

Signs/symptoms: Expiratory flow does not reach zero, ↓ BP, ↓ SpO2, ↓ ETCO2, wheezing.

Complications: Hemodynamic instability, baro/volutrauma, ↑ work of breathing

DDx: Bronchospasm (especially in asthma, COPD pts), pulmonary edema, pneumothorax, aspiration/ secretions, obstructed filters/tubing, ↑ RR.

Risk factors: Asthma, COPD, short expiratory time in ventilatory settings.

Management: Check for circuit malfunction, immediately disconnect pt from the ventilator and allow full expiration before reconnecting, ↓ tidal volume and ↑ I:E, treat underlying cause.

MYOCARDIAL ISCHEMIA/INFARCTION

Definition: Decreased blood flow to the heart from CAD or oxygen-demand mismatch leading to myocardial ischemia.

Signs/symptoms: ST elevation/depression, unexplained ↑ HR or ↓ BP, arrhythmias, new Q waves, new LBBB.

Complications: Cardiogenic shock, cardiac arrest.

DDx: Cardiac tamponade, arrhythmia, PE.

Risk factors: CAD/CHF and associated risk factors, vascular surgeries, major abdominal/ thoracic/ENT surgeries, significant bleeding.

Prevention: Identify pts at risk, perform appropriate pre-op optimization, risk-stratify CVS complications, 5 or 12 lead ECG, consider invasive BP monitoring.

Management: Varies significantly based on many factors such as reason for surgery/ urgency, type of surgery, pt condition and PMHx, timing and severity of ischemic event (e.g. before incision vs open abdomen), possible reasons for myocardial ischemia (and whether management would change), among others. General principles include maximizing myocardial oxygenation and decreasing demand. Consult cardiology for disposition and follow-up care if possible.

- Two very simplistic examples:
- e.g. ASA2, pre-incision, post-intubation, elective operation, new ECG changes → consult with cardiology, surgical team regarding best management plan (e.g. proceed or reschedule surgery, disposition)
- e.g. ASA5E, trauma surgery → pt would not survive without surgical intervention regardless; optimize myocardial and hemodynamic stability while minimizing surgical insult/time if possible. Management of acute ischemia/infarction most likely will occur after the surgery with cardiology in CCU/ICU.

The following material and images are adapted with permission from Dr David Parsons.

THE ANESTHETIC MACHINE

- Accurately mixes air, oxygen, and anesthetic gases; scavenges/recycles unconsumed gases
- Delivers gases to the pt in a monitored and precise manner
- Enables various ventilation strategies
- Operates as a **semi-closed circuit**:
    - **Fresh gas flow** enters the circuit from the wall supply and can be controlled by the anesthesiologist. The *concentration* and *flow rate* of the gases (oxygen, anesthetic gases) can be set separately (*fresh gas control*) or determined automatically by the machine if end-tidal concentrations are set (*end-tidal control*).
    - **Inspired concentrations** of gases from the circuit is what is inhaled by pt. This is determined by addition of gases to the circuit (the concentration and flow rate of the fresh gas flow), and by the elimination of gases by the patient (i.e. utilization of O2, redistribution of anesthetic gases to body tissues).
    - **End-tidal concentrations** of gases (CO2, anesthetic agents (i.e. MAC)) entering the circuit are measured in the pt's exhalation.
    - When fresh gas flow rate is high, the gas in the circuit will be similar to the fresh gas flows, since it equilibrates quickly. When the fresh gas flow rate is low, the gas concentrations in the circuit (thus the inspired concentration) may be quite different from the fresh gas flow since it may be consumed/eliminated by the pt faster than is being added to the circuit.

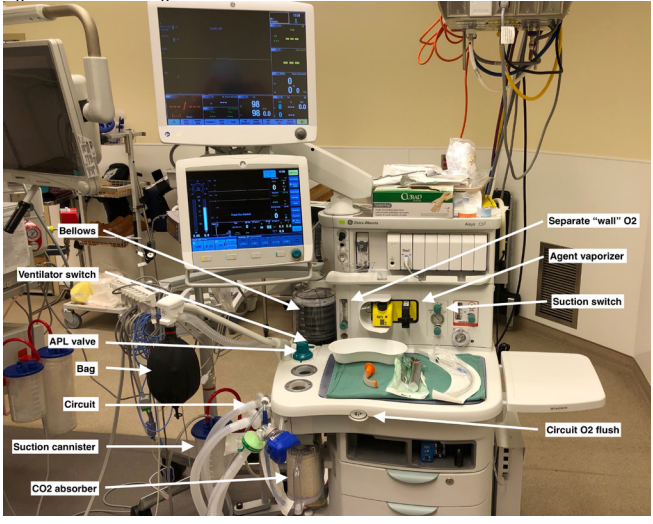
Note: Depending on the machine model, the specific layout/components may vary.

Components of the machine: (see labelled images following)

- **Bellows**: Pushes air through the circuit when the ventilator is ON. Some models may not have visible bellows.
- **Ventilator switch:** Turns ventilator on/off. May be integrated into the monitors on some machines.
  MAN/SPON (left) – Used for spontaneously breathing pts or when bagging manually.
  VENT (right) – Ventilator is on.
- **Adjustable pressure-limiting (APL) valve**: Controls the maximum circuit pressure when the ventilator is OFF (i.e. set to MAN/SPON).
  Spontaneously-ventilated pts: 0cm H2O
  Bagging by mask: <20 cm H2O (exceptions include emergencies like laryngospasm)
  Bagging by ETT: <40 cm H2O
- **Bag**: For manual ventilation (OFF). This will move during spontaneous ventilation, or you can manually ventilate if the APL >0 cm H2O.
- **Circuit:** Tubing that connects the machine to the pt.
- **Suction canister & suction**
- **CO2 absorber**: Removes CO2 from the circuit. Contents will change colour as CO2 is removed; should be replaced as needed.
- **Separate "wall" O2:** Functions like a regular oxygen regulator and is NOT connected to the main circuit.
- **Agent vaporizer**: Contains the volatile anesthetic gas. Must be removed from machine prior to refilling.
- **Suction switch**: Turns suction on/off.
- **Circuit O2 flush:** Flushes O2 into the circuit at high flow. Has to be used with caution if the pt is connected to the circuit.

Figure 3: Labelled image of an anesthetic monitor

Figure 4: Labelled image of an anesthetic machine



PREPARING THE OR: SOAP-IM

✔ Oftentimes, the room and equipment may already be prepared, but it is essential to perform a full check prior to every case.

S - Suction
- Prepare Yankauer & suction system
- Check pressure gauge to ensure suction tubing is connected properly

O - Oxygen
- Check circuit tubing connections, gas analyzer tubing, elbow, filter, and face mask
- Check for availability of backup O2 tank

A - Airway
- Prepare ETT, laryngoscope & oropharyngeal airway
- Check the laryngoscope by moving the blade into position & ensuring the light works properly.
- Check ETT cuff for leaks.
- Ensure availability of SGA & back-up ETT
- Know where to access the videolaryngoscope
- Prepare tape to secure ETT

P - Pharmacy
- Obtain medications that may not be available in the cart already
- Prepare and label medications
- Prepare rescue medications (e.g. phenylephrine, ephedrine; occasionally atropine, succinylcholine, vasopressors, nitroglycerin)
- Know where to access emergency carts (e.g. code cart, MH cart, difficult airway cart)

I - IV
- Check for appropriate IV fluids and sufficient IV access on patient

M - Monitors/Machine
- Check for standard monitors (pulse oximeter, NIBP, 3-lead or 5-lead ECG, ET gas analyzer)
- Check machine for leak test (perform leak test before every procedure:
  - Ensure the circuit can supply positive pressure:
    1. Turn the APL valve up past 20cm H2O.
    2. Occlude the end of the circuit (Y-piece) with your thumb.
    3. Pressure the O2+ flush button to fill the bag.
    4. Squeeze the bag & ensure it provides some resistance to deflation.

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Airway management, intubation, and emergencies

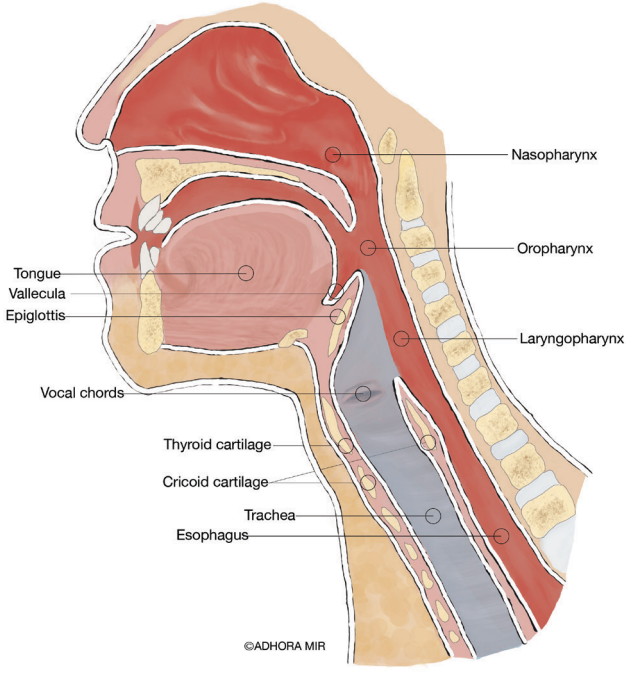
Section reviewer: Gwen Lovsted
Senior reviewer: Jacob Salituri, MD
Staff reviewer: David Lagrotteria, MD

Knowledge-based objectives:
- *Describe airway anatomy relevant to BMV and ETT.*
- *List indications for ETT, use of SGA, and indications for mechanical ventilation*
- *Describe criteria for extubation.*
- *List the causes of hypoxemia. Describe appropriate treatment of hypoxemia in the preoperative setting.*
- *List the types of patients who are at highest risk of aspiration. Explain how we prevent aspiration and describe how aspiration is treated.*

Essential Clinical Encounters objectives:
- *Discuss how airway management may be impacted by obesity. How about ventilatory strategies?*
- *List strategies to prevent laryngospasm on extubation. If laryngospasm does occur, how would you treat it?*
- *What is status asthmaticus and how would you manage that intraoperatively?*
- *Think of the potential challenges the anesthesiologist encounters when formulating an anesthetic plan for a patient coming for an emergency procedure. How can the surgical team facilitate that process?*
- *What are the indications for rapid sequence induction? Why is it more commonly done for emergency procedures? How is rapid sequence induction different from the usual elective induction?*
- *How would you determine if ventilation and oxygenation are adequate in BMV?*
- *What are the predictors of difficult BMV? Think of strategies to optimize BMV.*
- *How do you confirm adequate placement of an ETT?*
- *How would you select an appropriately sized ETT, and at what depth should it be inserted to at the teeth?*
- *When you insert a supraglottic airway, where would its tip be if adequately placed?*
- *Pros and cons of a supraglottic airway vs. an ETT. Think of clinical situations in which supraglottic airways may be used instead of an ETT.*
- *Describe the airway anatomy relevant for laryngoscopy and intubation. What are the main anatomical landmarks?*
- *How does the technique change if you are using a curved vs. a straight blade?*
- *Think of strategies to minimize tooth and lip damage during laryngoscopy.*
- *How is videolaryngoscopy different from direct laryngoscopy?*

Skills objectives:
- *Provide a patent airway in an unconscious adult patient, with or without the use of an airway device (oral or nasal airway), with minimal or no assistance.*
- *Demonstrate adequate ventilation using BMV technique with minimal assistance in the unconscious adult patient.*
- *Prepare airway equipment: laryngoscope, suction, styletted ETT, SGA.*
- *Position the unconscious adult patient or appropriate simulation device for insertion of an SGA or for performance of laryngoscopy with minimal assistance.*
- *Insert an SGA with minimal assistance in an unconscious adult patient or appropriate simulation device. Demonstrate attention to patient care and safety during insertion. Assess appropriate positioning of the device.*
- *Perform laryngoscopy and ETT with minimal assistance in an unconscious adult patient or appropriate simulation device. Demonstrate attention to patient care and safety during insertion. Assess appropriate positioning of the ETT.*

Figure 5: Sagittal view of the airway



BAG-MASK VENTILATION

✷ The best predictor of a difficult BMV/intubation is a prior history of difficult BMV/ intubation.

Difficult BMV predictors: BONES	**Difficult airway predictors: SHORT**
B - Beard O - bese N - No teeth E - Elderly S - Sleep apnea/Snoring	S - Surgery/Short neck/Small mouth opening H - History of difficult ventilation, Hematoma O - Obesity/Obstructive Sleep Apnea R - Radiation to the neck T - Tumour

Strategies to optimize BMV:

- Use the C-E hand position
- Pull the jaw upwards to the meet the mask
- Insert an oropharyngeal airway
- Ventilate in sync with spontaneous breathing (if possible)
- Two person BMV

Figure 6: Coronal posterior-anterio view of the larynx

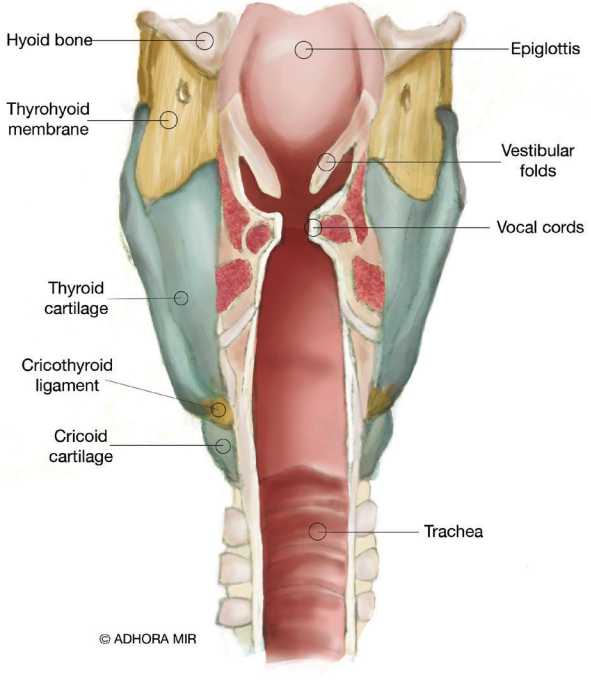
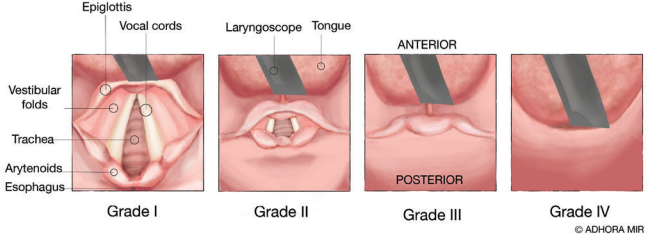


Figure 7: Cormack-Lehane classification system



INDICATIONS FOR INTUBATION/MECHANICAL VENTILATION

- Inability to maintain/protect airway (GCS <8)
- Failure to oxygenate
- Failure to ventilate
- Need for positive pressure ventilation >20mmHg
- Impending respiratory failure

✳ **Red flags:**
- SpO2 <90%
- PaO2 <60mmHg
- PaCO2 <35 or >45mmHg pH <7.25
- RR <8 or >30

LARYNGOSCOPE BLADES

Macintosh (curved) vs Miller (straight)
- **Macintosh blade** is inserted into the vallecula anterior to the epiglottis, whereas **Miller blade** is inserted posterior to the epiglottis and lifts it upwards while depressing the tongue for direct laryngoscopy.

Clinical uses of Miller (straight) blade:
- A big tongue or a very small mouth
- Short necks with a high larynx
- A fixed larynx from trauma, scarring, edema

Videolaryngoscopy utilizes a camera on a laryngoscope blade that allows indirect visualization of the vocal cords through a portable screen (e.g. GlideScope). Similar first pass success rates compared to direct laryngoscopy.
- Decreases the amount of force needed for laryngoscopy.
- Allows for glottic visualization when there is limited mouth opening, neck immobility/injury, or an anterior airway.
- Not reliable when there are secretions or blood in the pharynx.

DIRECT LARYNGOSCOPY AND INTUBATION

Materials: Gloves, appropriately sized blade and ETT, 10mL empty syringe, lubricating gel, lidocaine spray, stethoscope.

Sequence:
1. **Prepare:** Assemble equipment and put on gloves. Check ETT for working light bulb. Check cuff for leaks and prepare a 20mL syringe with air. Add some lubricant to the ETT.
2. **Position the patient:** Tilt head into sniffing position to optimize angles for laryngoscopy. Use scissor finger technique to open mouth. Hold blade in the L hand.
3. **Advance the blade:** Begin blade advancement along the R side of the tongue, which will sweep the tongue leftwards for better visualization. Apply light pressure and continue advancing into the oropharynx until the tip of the epiglottis is visualized. Continue advancement until the blade is in the valleculae.
4. **Visualize the cords:** Apply pressure in the direction of the laryngoscope handle (approx. 45°; keep elbow at side and do not lever the blade on teeth). Directly visualize the cords and note the grade of the view. May apply 1-2 sprays of nebulized lidocaine to cords.
5. **Intubation:** Maintain view of the cords and take the endotracheal tube in the R hand. Insert the tube until the deflated cuff is ~1-2cm past the vocal cords. Inflate the cuff until there is enough air to prevent leakage and avoid tracheal injury from overinflation (may be measured with manometer, ideal 20-30cm H2O).
6. **Verify for proper placement:**

- Stable ETCO2 waveform on capnography
- Direct visualization of ETT between the vocal cords
- Misting of tube on exhalation
- Bilateral breath sounds
- Bilateral chest rise
- X-ray or U/S visualization of ETT (for ICU purposes)

Tips for direct laryngoscopy:
- If you can't visualize the epiglottis, the blade may be too deep (in the larynx or esophagus) or too shallow (at the base of the tongue).
- Ask someone to apply BURP (backwards, upwards, rightwards pressure) to better visualize larynx.

Troubleshooting:
- **No ETCO2 / no breath sounds / epigastric gurgling on auscultation**: Esophageal intubation
- **Unilateral breath sounds/chest rise**: ETT may be inserted too far into mainstem bronchus (i.e. endobronchial intubation)
- **Low ETCO2**: Check cuff inflation for leaks, kinked tubing, airway obstructions, consider bronchospasm, consider hypotension/low perfusion/cardiac arrest.

Complications of intubation:
- Sore throat
- Airway edema
- Vocal cord paralysis
- Tracheomalacia

✷ Repeated attempts of intubation can lead to airway trauma and edema, making subsequent attempts more difficult. Plan for your first attempt at intubation to be your best attempt.

ELECTIVE INDUCTION

Indications: Routine induction (usual risk of aspiration) for elective surgeries in a sufficiently-fasted patient.

Sequence:

1. **Prepare:** Test suction and keep within easy reach. Apply some lubricant to ETT and check for proper seal of the cuff. Prepare a 10cc syringe with air for the cuff. Pre- oxygenate with mask for 3min or 5 vital capacity breaths.
2. **Induction + paralysis:** Typically begin with a hypnotic agent (e.g. propofol) and an opioid (e.g. fentanyl) to blunt SNS response to laryngoscopy/intubation, followed by a paralytic (e.g. rocuronium or succinylcholine).
3. **BMV:** Attempt to oxygenate the patient manually before proceeding to intubation.
4. **Intubation**: Perform laryngoscopy, insert ETT and inflate cuff.
5. **Check**: Verify the proper placement of the ETT/SGA.

RAPID SEQUENCE INDUCTION

Indications: Increased risk of aspiration (e.g. unable to protect airway, critically-ill, pregnant, emergent surgeries, full gastric contents).
Absolute contraindication: A known or anticipated difficult airway (must demonstrate ability to secure airway with BMV in case of failure to intubate).

Sequence: (differences from elective induction underlined)

1. **Prepare**: Test suction and keep within easy reach. Apply some lubricant to ETT and check for proper seal of the cuff. Insert a stylette into the ETT. Prepare a 10cc syringe with air for the cuff. Requires 3-5min or 6 vital capacity breaths for preoxygenation. Consider pre-induction placement of nasogastric tube to drain stomach contents. May ask assistant to apply and maintain cricoid pressure*.
2. **Induction + paralysis:** IV sedatives (e.g. propofol, fentanyl, midazolam, or ketamine) followed by immediate IV paralytic (rocuronium or succinylcholine).
3. **Period of apneic oxygenation** with no BVM awaiting peak paralytic effect (30s for succinylcholine, 45s for high-dose rocuronium).
4. **Intubation**: Insert ETT using direct/videolaryngoscopy). Inflate the cuff with 10cc of air.
5. **Check**: Verify the proper placement of the ETT. If cricoid pressure was used, only instruct for release after ETT placement has been confirmed.

* Utility of cricoid pressure is controversial and its practice varies by physician. Theoretically, the purpose is to compress the esophagus between the cricoid cartilage and the vertebral bodies, preventing aspiration of gastric contents during induction. It may, however, increase the difficulty of laryngoscopy, especially when applied incorrectly.

SUPRAGLOTTIC AIRWAY VS ENDOTRACHEAL TUBE

	SGA	ETT
Description	• Supraglottic airway device that maintains a patent upper airway for oxygenation/ventilation	• Definitive, gold standard airway for oxygenation/ventilation and aspiration protection when cuffed
Indications	• Short elective surgeries or limb surgeries (e.g. arthroscopic) • Spontaneous breathing is desired • Rescue device for difficult • airways • Conduit for difficult ETT • Prehospital airway management	• Long or emergency surgeries to avoid respiratory fatigue • Complete paralysis (e.g. • abdominal surgery) • Control of airway • pressure/volume, PPV (e.g. thoracic surgery, single lung) • Risk of aspiration
Contraindications	**Absolute**: Cannot open mouth, complete upper airway obstruction (surgical airway) **Relative**: Risk of aspiration, long/complicated surgeries, need for high airway pressure (>20cm H_2O, e.g. laparoscopic)	**Absolute**: Cannot open mouth, complete upper airway obstruction (surgical airway)
Position	Tip of SGA should be at the upper esophageal sphincter	Tip of ETT and cuff should remain between the vocal cords and carina
Depth	~8cm of tube will be protruding from mouth	Insert cuff ~2cm past vocal cords; total length is approximately 20cm (female) to 22cm (male) at front teeth
Size (approx)	Weight-based, may vary by brand – generally size 3-5 for adults.	Women: 7-7.5mm Men: 8-8.5mm

VENTILATION VS OXYGENATION

Ventilation is the exchange of air between the lungs and the environment (thus affecting PaCO2); **oxygenation** is the process of oxygen being added to the blood (thus affecting PaO2).

HYPOVENTILATION AND HYPOXEMIA

Risk factors for hypoventilation:
- Prolonged sedation period
- Opioid-induced respiratory depression
- OSA
- Obesity hypoventilation syndrome

Causes of hypoxemia:

Artifact • Incorrect probe position • Nail polish	**Hypoventilation** • ↓ Tidal volume • ↓ RR • Displaced/obstructed ETT, kinked line, equipment failure • Post-extubation: prolonged NMB, opioids, high spinal
↓ **PO2** • ↓ FiO2 • If on 100% FiO2: machine O2 failure • or gas mismatch	↓ **O2 delivery** • Diffusion problem (e.g. COPD, ILD) • Methemoglobinemia, carboxyhemoglobin
V/Q mismatch • Aspiration • Bronchospasm • Mainstem intubation • Embolism (air, fat, plaque, amniotic fluid) • Pneumo/hemothorax • Atelectasis • PMHx (e.g. asthma, COPD, ILD, CHF, pneumonia) • Patient positioning	↑ **O2 consumption** • MH • Sepsis • Thyroid storm/thyrotoxicosis

CRITERIA FOR EXTUBATION

1. **Adequate oxygenation** (SpO2 >92%, PO2 >60mmHg)
2. **Adequate ventilation** (spontaneous RR >7, ETCO2 <50mmHg)
3. **Hemodynamically stable**
4. **Adequate muscle strength** (TOF >0.9)
5. **Airway protection** (obey simple commands, cough/gag reflex)
6. Other: stable acid-base, lytes, volume, temp

Other considerations for extubation:
- Suction for secretions
- Bite block (to avoid pt obstructing tubing)
- Oropharyngeal airway if neeed
- Oxygen mask for transport and PACU

COMPLICATIONS & EMERGENCIES

General strategies for anticipated difficult intubation:
- Have a plan and be ready to call for help immediately; have backup equipment in room.
- Use an alternative anesthetic technique (i.e. regional, local) if appropriate.
- Perform awake intubation (pt maintains own airway until intubated).

(See Vortex approach and ASA difficult airway algorithm.)

Reasons for rapid deterioration/sudden cardiac arrest while intubated/ventilated: DOPES

D - Displaced ETT
O - Obstruction of ETT (secretions/mucous plug)
P - Pneumothorax / PE
E - Equipment failure
S - Stacking breaths (hyperinflation in asthma/COPD pts)

Diagnostic steps (process of elimination to determine source). Correlate clinically and with other monitors.

1. Turn FiO2 to 100%.
2. Switch off ventilator and initiate manual ventilation (equipment malfunction).
3. Inspect entire circuit from anesthetic machine to patient ETT (leaks, kinks).
4. Auscultate breath sounds bilaterally (pneumothorax, breath stacking).
5. Suction down ETT (secretions/mucous plug).
6. Disconnect ETT circuit (auto-PEEP; allow full exhalation).

ANAPHYLAXIS

Definition: A systemic allergic/hypersensitivity reaction to antigen leading to sudden release of inflammatory mediators by mast cell/basophil degranulation.

Signs/symptoms: ↓↓ BP, ↑ HR, ↓ O2, ↓ ETCO2, high peak airway pressures, shark fin (obstructive) waveform on capnography, dyspnea/wheezing, rash/urticaria.

Complications: Shock, cardiac/respiratory arrest.

Potential antigens: NMBAs, abx, sugammadex, latex products, blood products, IV contrast.

Management: Remove potential causal agents, epinephrine (10-100mcg IV bolus, increase dose q2min until clinical improvement), adequate fluid resuscitation, treat bronchospasm (SABAs, 4-8 puffs), early intubation (if not already and signs of angioedema/severe anaphylaxis), hemodynamic and ventilatory support and monitoring.

ASPIRATION

Definition: Inhalation of gastric contents into the trachea and lung.

Signs/symptoms: ↓ O2, ↓ HR, laryngospasm, bronchospasm.

Complications: Chemical pneumonitis, pneumonia, empyema, ARDS, cardiac arrest.

Risk factors: Emergency surgery, GERD, pregnancy, trauma, DM, recent food intake, bowel obstruction, obesity.

Prevention: Abide by NPO guidelines, ↑ gastric motility (e.g. metoclopromide), ↓gastric acidity (e.g. ranitidine), prophylactic anti-emetics, RSI, NG tube.

Management: Suction pharynx/trachea, R tilt to limit spread, 100% FiO2, CPAP/PEEP with lung protective strategies, bronchodilators; empiric abx NOT indicated unless signs of infection are evident.

BRONCHOSPASM

Definition: A reversible involuntary smooth muscle contraction in the bronchi leading to narrowed airways mediated by vagal innervation.

Signs/symptoms: ↓ O2, ↓ ETCO2, high peak airway pressures, shark fin (obstructive) waveform on capnography, dyspnea/wheezing, ↑ expiratory time, ↓ tidal volumes if pressure control ventilation.

Complications: Breath stacking/auto-PEEP (bronchospastic pts who develop sudden ↓↓ BP may be air-trapping).

Risk factors: Asthma, smoking, cold air, inhaled irritants, tracheal intubation/extubation.

Prevention: Pre-op prophylactic SABA/steroids, adherence to COPD/asthma therapy, topical lidocaine, ensure adequate anesthesia during intubation/extubation.

Management: 100% FiO2 with manual bag ventilation, change I:E ratio to allow for adequate exhalation, nebulized SABA (salbutamol, 6-8 puffs), IV steroids (e.g. methylprednisolone 1mg/kg IV), deepen anesthetic (ketamine and sevo/isoflurane have bronchodilatory properties).

LARYNGOSPASM

Definition: Partial/complete airway obstruction from laryngeal closure reflex (despite inspiratory attempts) due to chemical or mechanical stimuli.

Signs/symptoms: ↓ O2, ↓ HR, suprasternal indrawing, accessory muscle use, paradoxical breathing, stridor or silent chest.

Complications: Negative pressure pulmonary edema, cardiac/respiratory failure.

Risk factors: Pediatric pts, recent URTI, cigarette smoke exposure, emergency surgery, insufficient depth of anesthesia (higher risk during induction and emergence), oropharyngeal secretions.

Prevention: Consider delaying elective surgery 2-3w after URTI, apply topical lidocaine, ensure adequate anesthesia before intubation, extubate when deep or fully awake.

Management: Continuous positive airway pressure with 100% FiO2 with well-fitting mask and jaw thrust, suction secretions, deepen anesthetic with propofol, use paralytic (succinylcholine IV or IM), provide ventilatory support (consider reintubation if needed).

STATUS ASTHMATICUS

Definition: Extreme asthma exacerbation that is unresponsive to SABAs.

Signs/symptoms: ↓ O2, ↑↑ RR, ↑HR, prolonged expiration, stridor/wheeze/silent chest, accessory muscle use, suprasternal indrawing.

Complications: Altered mental status, pneumothorax, cardiac/respiratory failure.

Risk factors: PMHx hospitalization/ED for asthma, signs of inadequately-controlled asthma, URTI, cold air, inhaled irritants.

Management: 100% FiO2, IV SABAs, IV steroids, IV magnesium sulfate, ketamine or sevo/isoflurane, Heliox, monitor lytes (K+) and fluids. (Intubation is often not required in status asthmaticus and irritates the airway; it is usually reserved for impending respiratory failure.)

PNEUMOTHORAX

Definition: Gas in the pleural space leading to compression/collapsing of the lung.

Signs/symptoms: ↑ peak inspiratory pressures, ↓ O2, ↓ BP, ↑ HR, narrowed pulse pressure, decreased/asymmetrical breath sounds, tracheal deviation.

Complications: Tension pneumothorax, cardiac/respiratory arrest.

Risk factors: Trauma, COPD, spine or thoracic surgery.

Management: Check for mainstem intubation, 100% FiO2, stat U/S for lung sliding or CXR, needle decompression if hemodynamically unstable, thoracostomy, watchful waiting/supportive care if stable.

CAN'T INTUBATE, CAN'T OXYGENATE

Definition: A difficult airway that is unable to be intubated or ventilated by BMV.

Signs/symptoms: Failed intubation and ventilation, ↓ O2, cyanosis, respiratory failure.

Complications: Brain damage, death.

Risk factors: Hx of difficult BMV/airway, predictors of difficult BMV/airway.

Prevention: Identify at-risk patients, announce airway plan to team; have a Plan A (laryngoscopy), Plan B (alternate intubating technique), Plan C (supraglottic airway), Plan D (surgical airway) or wake pt if possible. Have all airway equipment available and ready.

Management: Limit intubation attempts (usually 3 attempts to minimize airway trauma), optimize between attempts (e.g. change position, call for expert, change blade/device), attempt SGA insertion, optimize BMV, oral/nasal airway, surgical airway (cricothyrotomy).

(See Vortex approach and ASA difficult airway algorithm.)

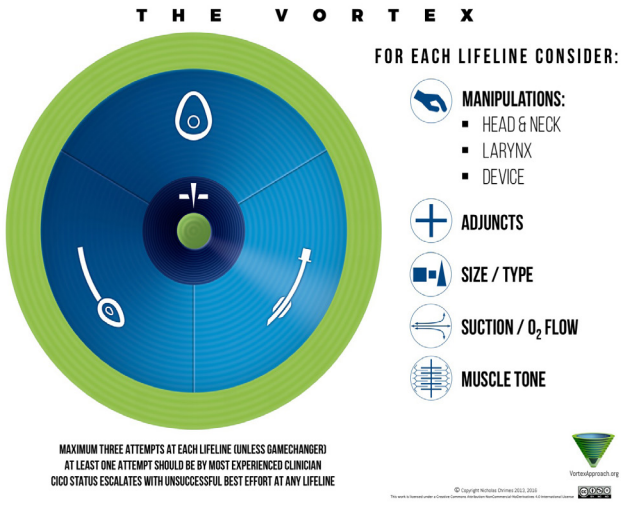
VORTEX APPROACH TO EMERGENCY AIRWAY MANAGEMENT

"The Vortex implementation tool is based on the premise that there are only three upper airway 'lifelines' (non-surgical techniques) by which alveolar oxygen delivery can be established and confirmed: face mask, supraglottic airway and endotracheal tube. If a 'best effort' at each of these three lifelines is unsuccessful then a can't intubate, can't oxygenate situation (CICO) situation exists and 'CICO Rescue' (emergency front-of-neck access) must be initiated.

"Completion of a 'best effort' at any of the three upper airway lifelines without being able to restore alveolar oxygen delivery mandates spiral movement inward towards the next lifeline. The circular arrangement of the three lifelines on the tool means that airway management can be initiated using any lifeline and proceed to the remaining ones in whatever sequence is judged most appropriate in the clinical circumstances. A list of five categories of optimisation, applying equally to each of the three lifelines, is provided to prompt consideration of the available options for maximising success during a best effort at any lifeline.

"Completion of best efforts at all three lifelines without restoring alveolar oxygen delivery culminates in spiral movement to the centre zone of the tool, representing the need to initiate CICO Rescue. Conversely, confirmation of alveolar oxygen delivery using any of the three lifelines, results in outward movement into the circumferential 'Green Zone'. The Green Zone prompts recognition of the opportunity to re-oxygenate, gather resources and develop a strategy, that arises whenever alveolar oxygen delivery is able to be established. The Green Zone is also visible in the centre of the tool to remind clinicians that, when all three lifelines have been unsuccessful, CICO Rescue also restores alveolar oxygen delivery and provides the same opportunities."

Read more at http://vortexapproach.org



ASA DIFFICULT AIRWAY ALGORITHM

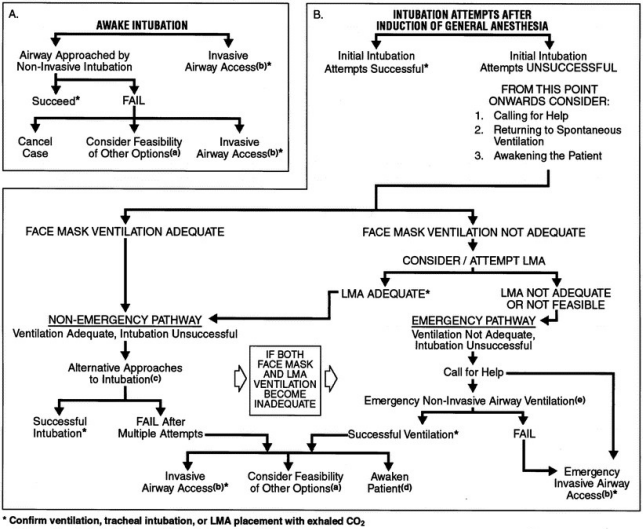
AMERICAN SOCIETY OF ANESTHESIOLOGISTS

DIFFICULT AIRWAY ALGORITHM

1. Assess the likelihood and clinical impact of basic management problems:
   - A. Difficult Ventilation
   - B. Difficult Intubation
   - C. Difficulty with Patient Cooperation or Consent
   - D. Difficult Tracheostomy
2. Actively pursue opportunities to deliver supplemental oxygen throughout the process of difficult airway management
3. Consider the relative merits and feasibility of basic management choices:

A.	Awake Intubation	vs.	Intubation Attempts After Induction of General Anesthesia
B.	Non-Invasive Technique for Initial Approach to Intubation	vs.	Invasive Technique for Initial Approach to Intubation
C.	Preservation of Spontaneous Ventilation	vs.	Ablation of Spontaneous Ventilation

4. Develop primary and alternative strategies:



*** Confirm ventilation, tracheal intubation, or LMA placement with exhaled CO_2**

a. Other options include (but are not limited to): surgery utilizing face mask or LMA anesthesia, local anesthesia infiltration or regional nerve blockade. Pursuit of these options usually implies that mask ventilation will not be problematic. Therefore, these options may be of limited value if this step in the algorithm has been reached via the Emergency Pathway.

b. Invasive airway access includes surgical or percutaneous tracheostomy or cricothyrotomy.

c. Alternative non-invasive approaches to difficult intubation include (but are not limited to): use of different laryngoscope blades, LMA as an intubation conduit (with or without fiberoptic guidance), fiberoptic intubation, intubating stylet or tube changer, light wand, retrograde intubation, and blind oral or nasal intubation.

d. Consider re-preparation of the patient for awake intubation or canceling surgery.

e. Options for emergency non-invasive airway ventilation include (but are not limited to): rigid bronchoscope, esophageal-tracheal combitube ventilation, or transtracheal jet ventilation.

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Fluid management and resuscitation

Section reviewer: Gwen Lovsted
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Knowledge-based objectives:
- *Describe how you would assess a patient's volume status.*
- *List potential sites for vascular access and complications associated with each site.*
- *Explain how euvolemia can be disturbed/altered in the preoperative period and how these alterations are managed.*
- *Describe appropriate uses for the following crystalloids: NS, RL, D5W, D5NS.*
- *Describe the rational use of blood product therapy. Explain the complications of massive transfusions.*
- *What information can be obtained from an arterial line?*
- *What happens when the arterial line transducer is too high or too low?*
- *Think of reasons you might decide to place an arterial line on a patient. Why are arterial lines sometimes done prior to induction and sometimes after induction?*
- *Describe the determinants of CO. Explain the relationship between myocardial oxygen supply and demand and how we can alter each aspect perioperatively.*
- *Define shock and explain how shock can be classified (type and degree). Describe potential treatments for the patient in shock, including the rational use of vasoactive and intrepid medications.*

Essential Clinical Encounters objectives:
- *Think of the potential challenges the anesthesiologist encounters when formulating an anesthetic plan for a patient coming for an emergency procedure. How can the surgical team facilitate that process?*

Skills objectives:
- *Prepare the equipment and supplies needed to insert an IV in an adult patient.*
- *Insert and IV in a conscious or unconscious adult patient or appropriate simulation device with minimal assistance. Determine the proper function of the IV line.*
- *Replace crystalloid solutions demonstrating sterile techniques and without air.*
- *Assess a patient's fluid/volume status (using history, physical exam, available monitors and laboratory investigations).*

DEFINITIONS

Crystalloid: Solutions with electrolytes that expand overall extracellular volume. ~1/3 volume stays in intravascular space; ~2/3 redistributed to interstitial space.

- **Normal saline (0.9% NS)**:
  Indications: Simple fluid replacement, use with blood products, hypoNa+, contraction alkalosis, traumatic brain injury.
  Cautions/contraindications: Metabolic acidosis, hyperCl-, renal dysfunction
- **Lactated Ringer's (RL):**
  Indications: Simple fluid replacement, less risk of metabolic acidosis/hyperCl-.
  Cautions/contraindications: Theoretical coagulation risk with blood products.
- **Dextrose 5% (D5W):**
  Indications: Give with insulin for ketoacidosis or hyperK+, hypoglycemia, hyperNa+.
  Cautions/contraindications: Uncontrolled DM, traumatic brain injury, hypoK+.

Colloid: Solutions containing large-weight particles that exert oncotic pressure in the plasma. Used less often than crystalloids.

- **Albumin:**
  Indications: Severe malnutrition, hepatic failure, burns, intravascular volume depletion.
  Cautions/contraindications: Circulatory overload, renal dysfunction, severe anemia.
- **Synthetic starches (dextran, hydroxyethyl starch):**
  Indications: (Rare usage) Hypovolemia, shock.
  Cautions/contraindications: Coagulopathies (↓vWF, VIII), CHF, renal disease. May cause renal toxicity and affect hemostasis/coagulation even without prior disease.

(mEq/L)	Na+	K+	Cl-	Lactate	pH	Osmolarity
Physiologic ECF (average)	140	4	103	100	7.4	295
0.9% NS	154	0	154	0	5.5	308
LR	130	4	109	28	6.5	273
5% albumin	130-160	<2	Varies	0	6.9	300

BLOOD THERAPY AND RELATED DEFINITIONS

Packed red blood cells (pRBC): Whole blood without plasma.
- **Indications**: Measured blood loss, inadequate oxygenation, indications for organ ischemia, Hb <70 unless symptomatic or rapidly decreasing.
- 1 unit = 300mL; raises adult Hb by ~10-15.

Fresh frozen plasma (FFP): Plasma with all coagulation factors except platelets.
- **Indications**: PT, INR, or both >1.5x normal.

Platelet transfusion: Just platelets.
- **Indications**: Usually not required intraoperatively unless platelets <50.
- Higher risk of transfusion-related infection.

Prothrombin complex concentrate (Octaplex): Contains factors II, IX, X (and heparin).
- **Indications**: Immediate warfarin reversal; coagulopathies; emergency surgery. Decreases INR faster than FFP.
- **Cautions/contraindications**: DIC, HIT.

Tranexamic acid (TXA): Inhibits fibrinolysis and promotes clot stability through inhibition of plasmin formation.
- **Indications**: Bleeding, reduce transfusion requirements.
- **Cautions/contraindication**s: Potential increased risk of thrombus formation, thromboembolic disease.

Type and screen: Blood test that determines ABO-Rh (type) and detects presence of common antibodies (screen). Reduces the incidence of hemolytic reactions.

Crossmatch: Blood test that determines the blood compatibility of a donor and recipient by checking for pre-formed antibodies to donor cells.

Uncrossmatched blood: Usually ordered stat for emergency transfusions.
- Can be type-specific, or type O if blood type is unknown.
- O+ for M>16 or F>45y.
- O- for F of childbearing age, pts <16 y/o, or known Rh- patients.

VASCULAR ACCESS SITES

Peripheral venous catheter: Most common type of vascular access. Begin distal to antecubital veins and move proximal if necessary. Avoid placement crossing wrist joint.

- **Indications**: Standard IV access site.
- **Cautions/contraindications**: Obstructed/stenosed vein, burn/infection over site, lymphedema or lymph node dissection in ipsilateral limb.

Central venous catheter (central line): Subclavian, internal jugular, femoral, or external jugular vein often used.

- **Indications**: Unable to access peripheral venous site, TPN, hemodialysis, administering meds (e.g. caustic, long-term abx), central venous pressure monitoring.
- **Cautions/contraindications**: Infection, obstructed/stenosed vein, burn site, coagulopathy.

Peripheral arterial line: Gold standard for BP monitoring. Radial artery preferred (other: ulnar, femoral, brachial, dorsalis pedis).

- **Indications**: Continuous direct monitoring of BP and MAP for hemodynamically-unstable patients; anticipated hemodynamic instability intra/post-op secondary to pt or surgical factors (e.g. potential for severe bleeding); frequent ABGs; severe obesity or inadequate NIBP cuff size.
- **Cautions/contraindications**: Absent pulse, artery vasospasm (choose new site), inadequate collateral circulation, coagulopathy, burn/infection over site, Raynaud's.
- The arterial line transducer will measure pressure in arteries of the same height; it is typically placed at the level of the right atrium (or the Circle of Willis for brain surgeries). Placement too high may underestimate the pressure; too low may overestimate.

Pulmonary artery catheter (PA/Swan-Ganz catheter): Catheter with balloon inflated in a pulmonary artery to measure pulmonary capillary wedge pressure as an indirect measure of left atrial pressure.

- **Indications:** Continuous measurement of blood gases/fluid requirements to optimize hemodynamic stability, pulmonary HTN, shock, cardiac surgery.
- **Cautions/contraindications:** R-sided endocarditis/tumors/masses, coagulopathy, R-sided valve disease.

COMPLICATIONS OF ACCESS:

- Infection
- Air embolism
- Pneumothorax (central lines)
- Heparin-induced thrombocytopenia
- Thrombosis (DIC, coagulopathies)
- Pain, neural injury
- Distal ischemia (arterial lines)

STARTING A PERIPHERAL IV

Materials: Alcohol wipe, gloves, rubber tourniquet, catheter/needle (usually 20G), saline flush or IV tubing, clear dressing (Tegaderm), tape, gauze.

Sequence:

1. **Prepare:** Assemble equipment. Prepare line by flushing with NS. Wash hands and put on gloves.
2. **Tourniquet**: Tie tourniquet above the elbow and use gentle fist pump and gravity to help locate veins.
3. **Choose a site**: Select a vein with an optimal path (e.g. start distal, avoid crossing joints) and lightly palpate to feel the vessel's edges and engorgement. Clean area with alcohol wipe in an outwards circular motion.
4. **Insertion of needle**: Use non-dominant hand to pull skin taunt below entry site (do not obstruct the needle's path). Insert needle (bevel-up) at shallow angle.
5. **Check**: Wait for flashback in chamber.
6. **Advance catheter**: Drop needle to 10°, advance a few mm further, then advance the catheter off the needle until it is entirely in the vein.
7. **Release tourniquet**: Release tourniquet while applying pressure directly above the entry site.
8. **Check**: Attach line and flush catheter; fluid should be easy to push through the catheter. Be aware of pain or swelling which may indicate an interstitial catheter. If so, remove IV, apply pressure to the site, and retry.
9. **Secure**: Apply Tegaderm and tape line to arm for security.

STARTING AN ARTERIAL LINE

Materials: Table, towels, and tape for positing, chlorhexidine swab, sterile gloves, arterial line kit (including catheter, needle, wire), sterile towels, 1-2% lidocaine and syringe, saline flushes, gauze, suture, clear dressing (Tegaderm), IV pressure bag.
***Note**: Consider using U/S for pts with known peripheral vascular disease/difficult access.*

Sequence:

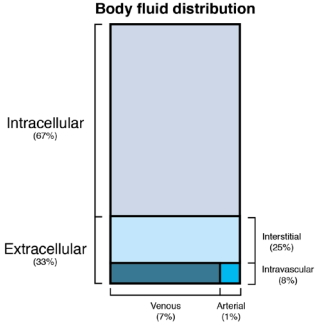
1. **Prepare:** Assemble equipment. Check for radial pulse; may perform Allen test to ensure adequate ulnar collateral supply. Dorsiflex wrist in a supine position by placing a rolled towel underneath the wrist and taping the fingers down to the table; sterilize skin and place sterile towels around area. Don sterile gloves.
2. **Landmark:** Take time to palpate the radial artery and assess the point of maximal impulse of the vessel using the tips of the finger.
3. **Local anesthetic**: Inject a small amount of subcutaneous lidocaine at intended puncture site.
4. **Double puncture technique**:
    - Advance catheter and needle (bevel-up) at 30-45° and wait for flashback in chamber. Advance needle and catheter through posterior arterial wall. Remove needle.
    - Slowly pull back on catheter until pulsatile arterial blood flow observed and then advance wire all the way into vessel.
    - Advance catheter into vessel following the wire, then remove wire while occluding artery proximally.
    - Attach IV tubing with pressure bag and transducer to catheter.
5. **Over the needle technique (Seldinger technique)**:
    - Advance catheter and needle (bevel-up) at 30-45° and wait for flashback in chamber, then advance slightly further to ensure catheter is in the vessel.
    - Drop needle at 10°, advance slightly more, then advance catheter fully.
    - Remove needle while occluding artery proximally
    - Attach IV tubing with pressure bag and transducer to catheter.
6. **Secure**: Either suture (generally in unconscious patients) or tape the line securely, then place clear dressing.

PREOPERATIVE VOLUME STATUS

✷ Fluid/volume status is very difficult to judge and most of our estimates based on clinical symptoms are not reliable. Consider looking at pre-op labs to help guide volume status assessment.

Hypovolemia
- **Causes**: Bleeding, vomiting/diarrhea, fever, sepsis (relative hypovolemia), trauma, burns, dehydration/NPO status/duration.
- **Sign/symptoms**: ↑ HR, orthostatic hypotension, capillary refill >3s, dry mucous membranes/axilla, intense thirst.
- **Labs**: ↑ Hct, hyperNa+, ↑ BUN:Cr, ↑ Cr

Hypervolemia
- **Causes**: AKI/CKD, cirrhosis, CHF, urinary tract obstruction
- **Sign/symptoms**: Pitting edema, stigmata of liver disease, ascites, crackles, wheezing, ↑ JVP
- **Investigations**: ↑ Pulmonary markings on CXR



INTRAOPERATIVE VOLUME STATUS

Consider:
- HR/BP trends
- Fluid balance: consider maintenance requirement, deficit, and replacement given; ins/outs prior to/during surgery

INTRAOPERATIVE BP MANAGEMENT

Classical management of intraoperative hyper/hypotension is to **maintain BP within 20% of preoperative BP**; however, some literature suggests that **absolute BP limits** may also be useful in preventing poor outcomes.

✷ Perfusion of organs generally requires **MAP >65**. However, must consider specific pt and procedure (e.g. BP cuff/arterial line transducer location relative to required surgical position, pts with chronic HTN, shifts in cerebral autoregulation).
✷ Always treat the underlying cause in addition to immediate temporary hemodynamic stabilization.

CO = HR x SV (SV depends on preload, contractility, afterload)
MAP = CO x SVR
MAP ≈ 2/3 DBP + 1/3 SBP

Pulse pressure = SBP - DBP
- Normal PP ≈ 40 at rest.
- **Causes of widened PP (>40):** aortic regurg, atherosclerosis, thyrotoxicosis, pregnancy, anxiety.
- **Causes of narrowed PP (<25):** aortic stenosis, coarctation, tension pneumo, MI, shock.

CLASSICAL FLUID MANAGEMENT

✔ The goal of fluid therapy is to optimize cardiac performance and hemodynamic stability. Consider other differentials for hypotensive pts before using fluid therapy.
✷ Both excessive and inadequate fluids are detrimental to outcomes. Goal-directed therapy should be individualized per pt and situation.

Ideal amount of fluids = Pre-op deficit + Intra-op loss + Unanticipated loss + Insensible fluid loss

4-2-1 rule:
4mL/kg/hr for first 10kg 2mL/kg/hr for second 10kg
1mL/kg/hr for every 10kg above 20kg

OR **40mL + (weight in kg)mL**

Preoperative loss:
4-2-1 rule x hours NPO = total mL

Maintenance:
1-1-1 rule x hours in surgery = total mL

Estimated intraoperative loss by surgery type:
Minimally invasive: 2-4mL/kg/hr
Moderately invasive: 4-6mL/kg/hr
Majorly invasive: 6-8mL/kg/hr

Unanticipated blood loss:
Replace loss with crystalloids in 3:1 ratio (i.e. 300mL crystalloid for every 100mL blood loss); balanced solutions like RL usually preferred.

Insensible loss:
Usually insignificant except in long open abdominal surgeries or burn patients.

COMPLICATIONS & EMERGENCIES

Included topics:
- Intraoperative hypotension
- Intraoperative hypertension
- Managing trauma
- Massive transfusion

INTRAOPERATIVE HYPOTENSION

Complications: Hypoperfusion leading to tissue hypoxia and end-organ injury (e.g. demand ischemia/MI, AKI, stroke)

Common causes of hypotension: SHOCKED

S – Sepsis
H – Hypovolemia, hemorrhage
O – Obstructive (PE, tamponade)
C – Cardiogenic (MI, arrhythmia)
K – anaphylaKsis
E – Endocrine (adrenal insufficiency)
D – Drugs (e.g. β blockers, calcium channel blockers, other anti-hypertensives; intraop use of opioids or volatile anesthetics)

Physiologic DDx: CO = HR x SV

↓ **PRELOAD** • Hypovolemia (hemorrhage, dehydration) • Cardiac tamponade • Decreased venous return (e.g. IVC compression, pneumoperitoneum) • PE • Increased thoracic pressure (e.g. auto-PEEP, pneumothorax)	↓ **CONTRACTILITY** • Cardiogenic shock/myocardial depression • MI • Medications
↓ **SVR** • Distributive shock (sepsis, anaphylaxis, neurogenic) • Medications	↓ **HR** • Cardiogenic shock/myocardial depression • Vagal stimulus • Medications

Management strategies:
✔ Temporize with fast-acting, short duration drugs (e.g. phenylephrine, ephedrine); determine and treat underlying cause.
- Use vasopressors, inotropes, or fluids for hemodynamic support (note: vasoactive meds may not work effectively in acidotic or hypoCa2+ states)
- Feel for pulse and check ECG (activate ACLS if needed)
- Turn down/off anesthetic agents
- 100% FiO2, reduce PEEP
- Consider Trendelenburg
- Maintain IV access or art-line, consider other monitoring options (e.g. CVP, TEE)
- Investigations/monitoring: acid-base status, ABG (pH), CBC, lytes/extended lytes, ionized Ca2+, lactate, INR/PTT, fibrinogen

INTRAOPERATIVE HYPERTENSION

Complications: End-organ injury (e.g. MI, AKI, stroke) and increased risk of hemorrhage.

DDx:

IATROGENIC:	**PT-RELATED**:
• Surgical stimulus (pain) = ↑ SNS • Stimulus from intubation • Inadequate anesthesia • Medications • Fluid overload • Hypercarbia	• Chronic HTN • Hypermetabolic state (e.g. thyrotoxicosis, malignant hyperthermia) • Endocrine disorders (e.g. pheochromocytoma) • ↑ ICP • Recreational drug user

Management strategies:
✔ Temporize with fast-acting, short duration drugs; determine and treat underlying cause.
• Deepen anesthetic or increase pain control
• Use short/long-acting vasodilators, β blockers

MANAGING TRAUMA

Primary survey: Rapid head-to-toe survey prioritizing most life-threatening injuries.

C - Control hemorrhage
✷ Massive life-threatening hemorrhage (e.g. intra-abdominal bleeding, lacerated femoral artery) must be aggressively prioritized to preserve circulation. Control through direct pressure or tourniquet if possible.
A - Airway and c-spine control
B - Breathing and oxygenation
C - Circulation and hemorrhage control
D - Disability
E - Exposure

✷ Assess pt for:
• Airway-compromising injury (e.g. burns, traumatic head, neck or spinal injury)
• Respiratory compromise (e.g. traumatic chest, lung or diaphragmatic injury, pneumothorax)
• Circulatory instability (e.g. hemothorax, intra-abdominal bleeding, massive hemorrhage including femur and pelvic fractures)
• Other injuries requiring immediate stabilization

A - Airway and c-spine control
• Maintain c-spine precautions with collar or manual in-line stabilization until cleared
• Airway *patent?* (Look, listen, feel) → suction, oral/nasal airway, jaw thrust
• Airway *protected?* (GCS >8, gag/cough/swallow intact) → if not, consider intubation

✷ Consider early intubation in pts with airway burns, oral trauma/bleeds, penetrating/blunt neck trauma.
• Assume full stomach and use RSI if intubation is indicated
• Make plans for difficult/failed intubation

B - Breathing and oxygenation
• Listen for bilateral breath sounds, inspect for chest rise, RR, colouring, monitor with pulse oximetry
• Inspect for open chest wounds, flail chest, unilateral chest movement, tracheal deviation
• Tension pneumothorax requires immediate needle decompression followed by chest tube placement

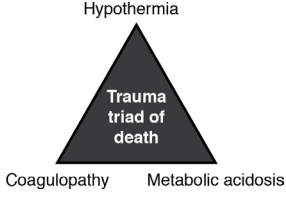
C - Circulation and hemorrhage control
- Control obvious hemorrhage
- Ensure IV access (two 14-16G peripheral catheters)
- Assess for circulatory compromise suggesting hemorrhagic shock: cool, mottled skin, weak pulses, hypotension, tachycardia
- Simultaneously assess and manage as necessary with fluid resuscitation and blood products
- Assess potential spaces for bleeding with POCUS: thoracic (cardiac tamponade, pleural effusion), abdominal, retroperitoneal/pelvic cavities
- For high volume transfusion, first rapidly infuse 1L warmed isotonic fluid followed by balanced transfusion (1:1:1 ratio for plasma:plts:pRBCs
- SNS overstimulation from injury may mask intravascular depletion

D - Disability
- Rapid neurological assessment (PERLA, GCS)
- Assess for signs of basal skull fracture (raccoon eyes, Battle's sign, otorrhea)
- Consider neurogenic shock

E - Exposure
- Fully expose pt to complete inspection (complete log roll, maintaining C-spine precautions)
- Avoid hypothermia by using warm blankets or bair hugger, warm fluids

Secondary survey: A full H&P after primary survey and adequate resuscitation is complete; pt must be hemodynamically stable. Assess particularly for trauma, MSK, neuro, chest and abdo.
- Inspect for signs of injury, stabbing or GSW, electrical entry/exit wounds
- Seat belt sign from MVC
- AMPLE Hx:
  - **A** – Allergies
  - **M** – Medications
  - **P** – PMHx
  - **L** – Last meal/NPO status
  - **E** – Events
- Insert foley catheter to monitor fluid status if necessary (unless there is suspected urethral injury)

Tertiary survey: 24h after initial presentation, reassess all results from H&P.
- Look at lab results, final imaging reports
- Look for any missed injuries, smaller injuries



MASSIVE TRANSFUSION

- The replacement of a pt's total blood volume or 10u in <24h.
- **Follow institutional massive transfusion protocols.**

Damage control resuscitation:

- Permissive hypotension
- Stop bleeding early
- Early use of blood products
- Minimize crystalloid use
- Minimize pressor use

Management strategies:

- 100% FiO2
- Establish 2x large bore IV or intraosseous lines
- Use rapid infuser and fluid warmer
- Consider Trendelenburg position
- Send blood for type and screen (or crossmatch); use uncrossmatched blood until available
- Investigations/monitoring: acid-base status, CBC, lytes/extended lytes, ionized Ca2+, INR/PTT, fibrinogen, ABG.
- Transfuse early and replace products as needed
- Balanced 1:1:1 for plasma:plts:pRBCs

$$\text{Estimated blood loss} = \text{Estimated blood volume} \times \left(\frac{\text{Original Hct - Measured Hct}}{\text{Original Hct}}\right)$$

- Estimate Blood Volume = 65-70% of body weight

Complications of blood therapy/transfusion:

Allergy

- **Signs/symptoms**: Rash, flushing, itching, dyspnea.
- **Complications**: Anaphylaxis, respiratory failure.
- **Management**: Treat according to severity of reaction (e.g. epinephrine, anti-histamines).

Coagulopathy: Dilutional coagulopathy from pRBCs, crystalloids/colloids.

- **Signs/symptoms**: Prolonged/excessive bleeding, chest pain, SOB, headaches.
- **Complications**: Prolonged hemorrhage, DIC, AKI.
- **Prevention**: Monitor patient for bleeds, viscoelastic testing, balanced transfusion.
- **Management:** Give FFP and plts, monitor INR and PT, plts, and fibrinogen.

Hemolytic transfusion reaction (immediate or delayed)

- **Signs/symptoms**: ↓ O2, ↓ BP, ↑ HR, ↑ RR, fever, chills, N/V, hemoglobinuria.
- **Complications**: AKI, DIC.
- **Prevention**: Double-check blood/ID before transfusion.
- **Management**: Stop transfusion immediately, provide ventilatory/hemodynamic support, monitor for DIC, maintain urine output with IV fluids diuretics.

Hyperkalemia: Occurs rarely in pts being transfused high amounts of blood directly into central circulation (e.g. infants through umbilical catheter).

- **Signs/symptoms**: Peaked T waves, wide QRS, loss of P wave, sine wave pattern on ECG.
- **Complications**: Cardiac arrest.
- **Prevention**: Use pRBC <10d old, wash pRBCs before infusion, monitor ECG.

Hypocalcemia: Citrate toxicity from FFP/plts/pRBCs.
- **Signs/symptoms**: Tetany, seizures, ↓ BP, ↓ pulse pressure, flat ST, ↑ QTc.
- **Complications**: Arrhythmias, seizures.
- **Prevention**: Follow maximum infusion rate especially for pts with hepatic insufficiency .
- **Management:** Slow IV injection of calcium gluconate 10% (10-20mL per 500mL pRBC), monitor lytes.

Hypothermia
- **Complications**: Arrhythmias, coagulopathy, ↓BP, hypoCa2+.
- **Prevention:** Warm blood products before transfusing, monitor temperature.
- **Management**: Fluid warmer, warm blankets/bair hugger.

Transfusion-Associated Circulatory Overload (TACO)
- **Signs/symptoms**: ↓ O2, ↑ BP, ↑ HR, ↑ RR, peripheral edema.
- **Complications**: CHF, cardiogenic pulmonary edema.
- **Prevention**: Prophylactic diuretics in fluid-positive pts (e.g. CHF, cirrhosis), slow transfusion speed.
- **Management**: Stop transfusion immediately, provide ventilatory/hemodynamic support, diuretics.

Transfusion-Related Acute Lung Injury (TRALI): ARDS onset <6h of transfusion.
- **Signs/symptoms**: ↓ O2, ↑ BP, ↑ HR, ↑ RR, fever.
- **Complications**: Non-cardiogenic pulmonary edema, respiratory failure.
- **Prevention**: Avoid blood donated by multiparous women, leukoreduction.
- **Management**: Stop transfusion immediately, provide ventilatory/hemodynamic support.

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Pain control

Section reviewer: Lauren Riehm
Senior reviewer: Natalie Lidster, MD
Staff reviewer: Rafik Bolis, MBBCh

Knowledge-based objectives:
- *Describe modalities used to control pain in the perioperative period: opioids, NSAIDs (including acetaminophen), steroids, regional techniques, and local anesthesia. Explain how analgesics are used in a multimodal fashion.*
- *Describe common side effects of the commonly-used analgesic techniques.*

Essential Clinical Encounters objectives:
- *When planning for "acute on chronic pain" management, why is it crucial to know what and how much pain medication a patient is already taking prior to surgery?*
- *What does it mean to use a multimodal pain management strategy? Think of examples to minimize opioid requirements.*

Skills objectives:
NA

DEFINITIONS

Nociceptive pathways include: primary afferent neurons, spinal interneurons and ascending tracts, supra spinal areas.

Pain pathway and therapies:

Stage of pain processing	Transduction	Transmission	Modulation	Perception
Primary location	Tissue	1°, 2°, 3° neurons	Dorsal horn of the spinal cord	Thalamus, cortex
Role	Noxious stimuli converted into action potentials	Transmission of action potentials	Inhibition or augmentation of pain signals	Integration of input in somato-sensory/limbic cortex
Possible therapies	NSAIDs Anti-histamines Local anesthetics SNRI/SSRI Opioids	Local anesthetics	NSAIDs NMDA antag-onists SNRI/SSRI Opioids	General anes-thetics α2 agonists Opioids

Acute pain: A physiological response to a known stimulus (e.g. mechanical, thermal, chemical) that may interfere with quality of life; should disappear with healing over time.
- e.g. surgical incision, sprained ankle, labour pain, episodic headache.
- **Hyperalgesia**: Exaggerated pain response to typically painful stimulus.
- **Allodynia**: Painful response to typically unpainful stimulus.

Chronic/persistent pain: Pathological response and progression of acute pain if left untreated; typically persists for >3 months and interferes with quality of life.
- e.g. lower back pain, fibromyalgia, diabetic neuropathy, post-herpetic neuralgia.

Neuro-endocrine stress response: Nociceptive stimuli can lead to a physiological stress response; this can lead to clinically-significant increases in morbidity and mortality if unmanaged.
- ↑ SNS response, ↑ catecholamines, hypermetabolic state, ↑ O2 demand, ↓ GI motility
- ↑ catabolic hormones, ↑ coagulability, hyperglycemia
- Immunosuppression, ↓ wound healing
- Muscle spasms and splinting reflex, atelectasis

Multimodal analgesia: A combination of different classes of drugs to maximize analgesia provided by targeting different aspects of the pain pathway and minimizing adverse side effects of individual drugs.
- e.g. opioids, local anesthetics, NSAIDs, anti-depressants, cannabinoids, serotonin agonists, anti-epileptics.

Opioid: A class of drugs that bind to opioid receptors (mu, kappa, delta), primarily located in the brain stem, spinal cord, and peripheral organs (e.g. GI), causing analgesia without amnesia or general anesthesia.
- e.g. morphine, codeine, oxycodone, hydromorphone, fentanyl, remifentanil.
- **Common adverse effects:** ↓↓ RR, ↓ HR, N/V, histamine release, ileus/constipation, and urinary retention. Effects/overdose can be temporarily reversed with naloxone.

- The “right” dose of an opioid balances adequate pain relief with appropriate caution of the side effects. This should be titrated to response per pt. Consider age, tolerance, concurrent meds, severity of pain.
- **Tolerance**: Physiologic adaptation to a drug which requires increased doses to produce the same effects that were previously elicited by smaller doses.
- **Dependence**: Physiologic adaptation to a drug which elicits a withdrawal syndrome when the drug is decreased or removed.
- **Addiction**: When repeated use of a drug that triggers reward/pleasure creates a drive to use the drug, which may result in preoccupation, craving, compulsion, or continued use of the drug despite harm.

Patient-controlled analgesia (PCA): A method of receiving IV analgesia (via a pump connected to the IV line) where the patient self-administers small IV boluses of opioids on a self-determined basis rather than relying on a health care provider.

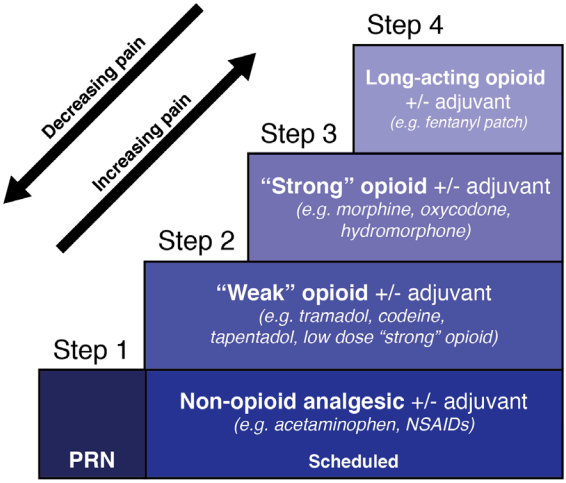
- Can help avoid peaks (over-sedation) and troughs (pain) associated with intermittent injections and increase duration of therapeutic concentrations.
- Safety mechanisms (e.g. lockout intervals, 1 or 4h limits) must be in place to avoid misuse and overdose.

MANAGING PAIN USING THE ANESTHETIC LADDER APPROACH

Analgesic ladder: A step-wise framework to escalating/deescalating analgesics, originally created for managing cancer pain.

1. **Acetaminophen and NSAIDs**
2. **Weak opioid**
   - ✶ Be cautious of overdosing acetaminophen with combination drugs (e.g. Percocet). Certain “weak” opioids (e.g. codeine, tramadol, tapentadol) depend on hepatic metabolism (CYP2D6) to convert into active metabolites; certain pts can experience very different levels of pain relief depending on genetic variation in CYP system.
3. **Strong opioid**
4. **Long-lasting opioid**
   - May consider adjuvants (e.g. NMDA antagonists, anticonvulsants, steroids, anti-depressants) before escalating opioid therapy.

Figure 8: WHO analgesic ladder



Breakthrough pain: A sudden increase in pain in pts with acute or chronic pain that lasts for a short time which is not controlled with their usual pain meds.

✔ Use same medication with PRN orders (e.g. IV morphine with PRN morphine bolus).

Managing acute-on-chronic pain

✔ Pts should continue their usual pain medication in perioperative period.

- Doses for acute pain is escalated in pts with a hx of chronic pain.
- Consider regional anesthesia techniques or IV local anesthetic to decrease opioid requirements and provide post-op pain management.
- Titrate opioid dose to RR when possible at the end of a case (RR 8-10) to avoid overdosing.

Non-pharmacologic methods of pain control:

Acute or chronic pain:	**Chronic pain:**
• Meditation • Music therapy • Massage therapy	• Interventional procedures (e.g. spinal cord stimulators, transcutaneous electrical nerve stimulation (TENS)) • Acupuncture

See also 2017 Canadian Guideline for Opioid for Chronic Non-Cancer Pain for more information and resources (http://nationalpaincentre.mcmaster.ca/guidelines.html).

GENERAL ANESTHESIA

- Analgesia during general anesthesia is accomplished with systemic (IV) therapy so medications are limited to this route of administration.
- With time and experience, it's possible to anticipate analgesic requirements for most patients undergoing most surgeries; medication is typically titrated to the signs of the patient's stress response (e.g. HR, BP, RR, movement).

REGIONAL ANESTHESIA

Benefits to regional anesthesia

- Better patient satisfaction (e.g. ↓ PONV, longer post-op analgesia)
- Protected airway and spontaneous ventilation
- Maintain CNS function (e.g. carotid surgery, transurethral resection of the prostate)
- Reduced blood loss
- ↓ opioid requirements/usage

Routes of regional anesthesia

Topical: Application of anesthetic through cream/gel/spray to a surface.

Infiltration: Injection of anesthetic subcutaneously or into surrounding tissues. Often used as preparation for other regional techniques (e.g. neuraxial).

- May use epinephrine as adjunct to provide local vasoconstriction and improve block.

IV regional (Bier block): Short-term (<1h) use of IV local anesthetic (0.25-0.5% plain lidocaine) in a limb (procedure for hand/foot) that is occluded from systemic circulation through a tourniquet. Anesthetic diffuses across vasculature into tissues.

- Be vigilant of unintended tourniquet release to prevent local anesthetic systemic toxicity.

Peripheral nerve/plexus block: Injection of anesthetic as close as possible to peripheral nerves or nerve plexuses.

- Can use pt sensation of paresthesias, nerve stimulation, U/S to locate nerves.
- Be vigilant for local anesthetic systemic toxicity or direct injury to nerves.

Neuraxial: Injection of anesthetic into the epidural or subarachnoid space. A spinal (subarachnoid) injection has faster onset and requires much less anesthetic than epidural. *(See Obstetrical Anesthesia section for more information on neuraxial techniques.)*

- Opioids may be used as an adjunct for improved analgesia.
- Be vigilant for local anesthetic systemic toxicity, high spinals, and hemodynamic changes (e.g. ↓ BP, ↓ HR).

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Obstetrical anesthesia

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Knowledge-based objectives:
- *Describe the physiologic changes associated with pregnancy and explain their implication on anesthetic management.*
- *Describe modalities of analgesia used in labour and delivery.*
- *Describe the anesthetic management of the patient undergoing Caesarean section.*
- *Describe the anatomy relevant to epidural or spinal anaesthetic techniques. Explain the role of regional anesthesia in modern anaesthetic practice.*

Essential Clinical Encounters objectives:
- *What are the structures that spinal needle passes through while being inserted? Think anatomically about how a spinal anesthetic is different from an epidural.*
- *What are some contraindications for neuraxial anesthesia or lumbar puncture?*
- *What are signs of local anesthetic toxicity?*

Skills objectives:
NA

PHYSIOLOGICAL CHANGES IN PREGNANCY

System	Physiological changes	Implication
CVS	↑ intravascular volume	• Not proportional to ↑ Hb = physiologic (dilutional) anemia of pregnancy
	↑ CO	• ↑ stroke volume, ↑ HR
	↓ SVR	• Potential ↓ BP
	Compression of IVC (2nd trimester)	• ↓ venous return = ↓ BP
Pulmonary	↑ upper respiratory tract soft tissue edema	• Potential difficult airway • ↑ bleeding risk
	↓ FRC = ↓ oxygenation ↑ O2 consumption	• Preoxygenate, RSI to prevent significant apnea • ↑ metabolic demands
	↑ minute ventilation	• ↑ IRV, ↑ tidal volume, ↑RR • ↓ PaCO2
	↓ lung volumes	• Rapid desaturation • ↓ FRC, ↓ ERV • ↓ MAC
Hematological	↑ erythrocyte volume	• Not proportional to ↑ intravascular volume = physiologic anemia of pregnancy
	↑ coagulation factors	• ↑ INR/PTT • ↑ coagulability and complications
	↑ WBC	• Mild leukocytosis unrelated to infection is common during pregnancy
	↓ platelet count	• Mild thrombocytopenia is normal (not usually <70,000)
GI	↓ gastric emptying (during labour only); ↓ lower esophageal sphincter tone	• ↑ aspiration risk • All pregnant patients >20w assumed to have a full stomach

CNS	↑ sensitivity to certain volatile and neuraxial local anesthetics	• Faster induction and emergence • ↓ spinal/epidural dose necessary • ↓ MAC
	↑ epidural vein engorgement ↓ epidural space	• ↑ risk of puncturing vessels • ↑ local anesthetic spread in epidural-space = lower doses required
Renal	↑ renal blood flow and eGFR by 50% by 2nd trimester	• ↑ clearance of Cr, urea, and uric acid during pregnancy

NEURAXIAL VS GENERAL ANESTHESIA FOR C-SECTION

Neuraxial advantages/indications:
- Mother remains awake during/after
- delivery
- Minimize maternal morbidity
- Avoid manipulation/potential loss of the airway
- Maintain airway reflexes/avoid aspiration
- ↓ immediate neonatal depression
- ↓ operative blood loss
- Potentially ↓ VTE incidence and site infection

General anesthesia advantages/indications:
- Emergency C-section (e.g. non-reassuring fetal status, cephalopelvic disproportion, arrest of dilation)
- Pts with contraindications to neuraxial anesthetic
- Failure of neuraxial anesthesia

CONTRAINDICATIONS TO NEURAXIAL ANESTHESIA

Absolute	Relative
• Pt refusal • Severe coagulopathy (e.g. frank DIC, very low plts) • Infection/burn injury at site of injection	• Valvular disease (e.g. aortic stenosis) • Neurological disorders (e.g. MS) • ↑ ICP • Previous back injury/surgery/lesion • Sepsis • Unresolved hypovolemia/hypotension • Bleeding pt

Labour pain

Stage 1 (in utero, visceral pain)	T10-L1
Stage 2 (active delivery)	T10-S4

Differential block: Different nerve fibers have different sensitivities to local anesthetics. This variation is dependent on factors such as myelination and axonal diameter.

More sensitive to local anesthetic → less sensitive to local anesthetic
Sympathetic nerves → temperature → pain → touch → pressure → motor

EPIDURAL ANALGESIA AND ANESTHESIA

Indications: Labour analgesia, surgical anesthesia (mainly for C-section).

Considerations: Pts usually conscious, PCA function available, offers post-op analgesia, slow onset and adjustability; may be used in pts with hypertension, pre-eclampsia, or other chronic pain conditions.

Complications: Post-dural puncture headache (PDPH), failure of block, motor block, inadvertent intrathecal (high or total spinal), intravascular injection (local anesthetic systemic toxicity), epidural hematoma/abscess (incidence ~0-0.6 in 100,000), temporary or permanent nerve damage, meningitis (incidence ~0.2-1.3 in 10,000).

Other side effects: ↓ BP, ↓ HR, pruritus, N/V, urinary retention, shivering, fever, back ache, bruising at site.

SPINAL ANESTHETIC

- Procedure is similar as epidural process (see below) though uses thinner needle (24-27G).
- Baricity is the density of a solution compared to CSF (e.g. hyperbaric = denser than CSF = will sink relative to injection site). It is affected by positioning.

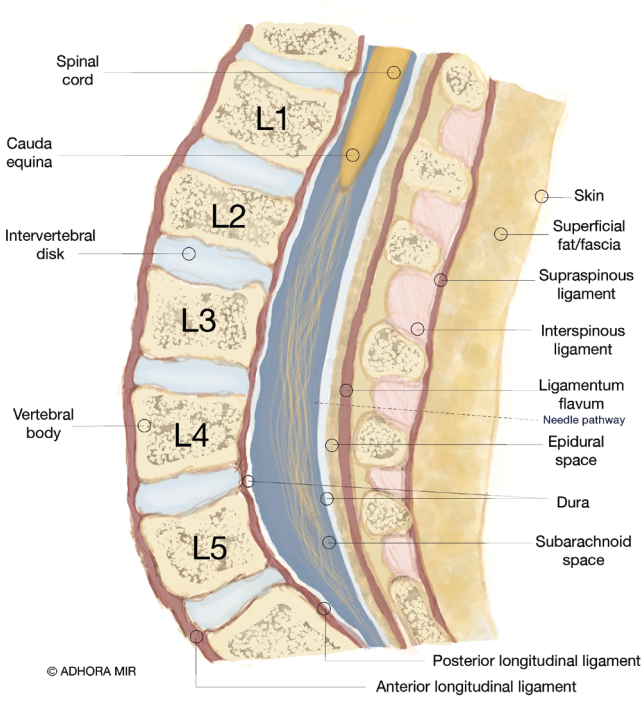
Indications: C-section anesthesia, less commonly used for labor analgesia (unless used as part of a combined spinal epidural technique).

Considerations: May be used in urgent situations as it may be performed quickly, only one injection is required, and has a faster onset of effects compared to an epidural.

Complications: PDPH, inadvertent spread (high or total spinal), excessive anesthetic given, temporary or permanent nerve damage, epidural abscess/hematoma, meningitis.

Other side effects: ↓ BP, ↓ HR, pruritus, N/V, urinary retention, shivering, fever, back ache, bruising at site.

Figure 9: Anatomy of lumbar spine



SPINAL VS EPIDURAL ANESTHESIA

	Spinal	Epidural
Pro	• Rapid onset • Symmetric block • Technically easier to perform • Lower failure rate • Lower doses needed	• Relatively slower onset • Can prolong block (top up via catheter) • Post-operative analgesia
Con	• Limited duration • Harder to prolong block • Requires dural puncture (risk of • PDPH)	• Relatively slower onset • Risk of patchy block • Risk of PDPH • Higher doses needed • Have to time removal considering anticoagulation/DVT prophylaxis

Neuraxial sequence:

1. **Position the patient:** Lateral decubitus or sitting to flex the spine.
2. **Landmark**: Superior iliac aspect of crest approximates L4 (Tuffier's line); palpate between chosen spinous processes in the midline.
3. **Local anesthetic**: Apply antiseptic, sterile drapes and administer local anesthetic wheal.
4. **Puncture**: Insert needle (18-24G commonly used depending on scenario) bevel up with stylet at ~10-15° cephalad. Advance into interspinous ligament (~2-4cm).
   ✳ ***Spinal technique only:*** *Advance needle until dura reached at ~5cm; feel 'pop' or loss of resistance once dura is punctured. Remove stylet and watch for CSF to confirm placement in subarachnoid space. Administer anesthetic slowly (<0.5mL/s) and then remove introducer, syringe, and needle simultaneously.*
5. **Loss of resistance**: Attach syringe of 2-3mL air/saline and check plunger between incremental needle advancements for loss of resistance. Epidural space is entered when there is smooth collapse of the plunger. (Lig flavum reached at ~4cm depth but can be highly variable.)
6. **Insert catheter**: Note insertion length of needle and insert catheter through needle 3-5cm more than the depth of the epidural space. Withdraw the needle while maintaining the catheter.
7. **Check**: Attach syringe to catheter and aspirate (blood, CSF should be absent). Give test dose (3mL 1.5-2% lidocaine + 1:200,000 epinephrine) and watch for symptoms of intravascular (↑ HR 20-30bpm, metallic taste, tinnitus) or intrathecal (leg motor/sensory loss - wait 3-5 min) injection. If negative, proceed.
8. **Inject**: Give anesthetic, tape catheter securely, and set up continuous infusion.

✳ **Do not advance needle upon pain or paresthesias** (may be touching spinal cord or nerve). Withdraw and reposition needle.
✳ **Co-loading** (fluid bolus simultaneous to administering neuraxial anesthetic) and use of **vasopressors** may help combat neuraxial-induced hypotension.

COMPLICATIONS & EMERGENCIES

SUPINE HYPOTENSION SYNDROME

Definition: Obstruction of venous return through IVC due to compression by gravid uterus when supine; may decrease preload by 10-20%.

Signs/symptoms: ↓ BP, N/V, pallor, diaphoresis, ↑ HR, altered mental status.

Prevention/management: Shift the uterus off the IVC by using a right hip wedge (15-30°); angle may be increased if patient is still symptomatic.

PRE-ECLAMPSIA/ECLAMPSIA

Definition: New-onset HTN (systolic >140 or diastolic >90) after 20w gestation with significant proteinuria or end-organ dysfunction. May progress to HELLP syndrome if severe or eclampsia if there is onset of seizures.

Signs/symptoms: Headache, visual changes, ↑ IOP, N/V, epigastric/abdominal pain, liver tenderness, pulmonary edema, IUGR, HELLP, seizures (eclampsia).

Management: Control acute severe BP (labetalol, hydralazine, nicardipine XL, nifedipine), IV magnesium sulfate until delivery, consider art-line, frequent CBC/lytes/renal/liver function, continuous fetal monitoring, preparation of general anesthesia if regional contraindications.

AMNIOTIC FLUID EMBOLUS

Definition: A sudden-onset maternal anaphylactoid reaction to amniotic fluid entering systemic circulation leading to CVS collapse and massive coagulopathy/bleeding. Requires diagnosis of exclusion. Incidence between 1/8000 to 1/83,000 live births.

Signs/symptoms: Respiratory distress, ↓ O2, ↑ HR, ↓ BP, bleeding, altered mental status, unexplained fetal compromise.

Complications: Seizures, DIC, arrhythmias, right heart failure, cardiac arrest.

DDx: Eclampsia, hemorrhage, air/pulmonary embolism, aspiration, anaphylaxis, anesthetic overdose (medication error, local anesthetic systemic toxicity, total spinal), sepsis, MI, valvular disease.

Management: Prepare for emergent C-section and/or massive transfusion, RSI, left lateral tilt, establish large bore IVs and temporize appropriately, place art-line, hemodynamic and ventilatory support (may require ECMO or cardiopulmonary bypass).

POST-PARTUM HEMORRHAGE

Definition: Loss of >500mL (vaginal) or 1L (C-section) within 24h following delivery.

Signs/symptoms: Vaginal bleeding, ↓ BP, ↑ HR, hemorrhagic/hypovolemic shock.

DDx:

Tone (uterine atony)
Trauma (e.g. uterine rupture, laceration)
Tissue (e.g. placenta accreta, retained or abrupted, blood clot)
Thrombus (e.g. DIC, ITP, TTP, HELLP, vWD, hemophilia)

Management: 100% FiO2, prepare for intubation/conversion to GA, consider massive transfusion protocol, establish large bore IVs and temporize appropriately, uterine mas-

sage/compression, uterotonics (e.g. oxytocin, carboprost, misoprostol), TXA, place art-line to monitor for hemodynamic instability, surgical intervention, frequent CBC/ABG/INR/PTT/fibrinogen.

LOCAL ANESTHETIC SYSTEMIC TOXICITY

Definition: Toxicity of local anesthetic due to injection into the systemic circulation or highly vascular area, or usage of an excess amount. Symptoms usually show within 1-5min. Systemic absorption varies by location (BICEPS): Blood (IV) > Intercostal > Caudal > Epidural > Plexus (brachial) > Subcutaneous. Incidence ~0.04-1 in 1000.

Signs/symptoms:

CNS:

Early: Tinnitus, blurred vision, slurred speech, dizziness, agitation, muscle twitching, seizures

Late: Drowsiness, unconsciousness, apnea.

CVS:

Early: ↑ HR, ↑ BP

Late: ↓↓ BP, ↓↓ HR (conduction block, long PR, wide QRS), ventricular dysrhythmias, cardiac arrest.

DDx: Anaphylaxis, cocaine toxicity, tricyclic antidepressants, anxiety

Prevention: Use minimum effective dose, aspirate prior to injection, incremental injections, added epinephrine may be warning, monitor pt and ask about symptoms.

Management: Stop local anesthetic administration, treat seizures, 20% lipid emulsion infusion (Intralipid), hemodynamic and ventilatory support.

HIGH REGIONAL BLOCK/TOTAL SPINAL

Definition: Unintended spread of anesthetic affecting spinal nerves above T4; a total spinal is the intracranial spread of anesthetic. Symptoms usually show within 1-5min. Incidence ~1 in 4300.

Signs/symptoms:

Total spinal: Slurred speech, dizziness, rapid rising sensory block, loss of consciousness.

C3-C5: Respiratory distress, ↓O2, symmetric shoulder weakness.

C6-C8: Respiratory distress, symmetric arm/hand weakness, paresthesia.

T1-T4: ↓ BP, ↓ HR, N/V.

DDx: Isolated spinal hypotension, local anesthetic systemic toxicity.

Prevention: Use low dose anesthetics and consider the level of block needed, aspirate before injection, consider giving epidurals in divided doses, inject slowly.

Management: Stop neuraxial anesthetic administration, 100% FiO2 or RSI, left lateral tilt, monitor fetal HR, establish large bore IVs and temporize bradycardia/hypotension appropriately, hemodynamic management and ventilation until block wears off.

POST-DURAL PUNCTURE HEADACHE (PDPH)

Definition: A headache due to leakage of CSF, intracranial hypotension, and venodilation from a puncture of the dura during a neuraxial technique. Symptoms typically self-resolve within 1-2wk. Incidence ranges from 2-10% depending on technique/needle in obstetric pts.

Signs/symptoms: Radiating dull headache (exacerbated by movement/sitting or standing, relieved by lying down), neck ache, backache, N/V, vertigo, dizziness, tinnitus, hearing loss.

DDx: Intracranial hemorrhage/hematoma, migraine, tumour, meningitis, central venous thrombosis, non-specific headache.

Prevention: Fine-gauge (25-27G) needles, pencil point tip, avoid inadvertent puncture of the dura (operator expertise).

Management: Supportive therapy (e.g. bed rest, NSAIDs, rehydration), pharmacologic/interventional therapy (caffeine, epidural blood patch).

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Pediatric anesthesia

Section reviewer: Jared Cohen
Senior reviewer: Russell Lenferna, MD
Staff reviewer: Amanda Whippey, MD

Knowledge-based objectives:
- *Describe the main physiologic differences between pediatric and adult patients and explain their implication on anesthetic management.*
- *Explain the fluid management issues of the pediatric patient.*
- *Calculate appropriate ETT size for pediatric patients.*

Essential Clinical Encounters objectives:
NA

Skills objectives:
NA

ANATOMIC DIFFERENCES IN CHILDREN

Area	Anatomic changes	Implication
Head	Larger occiput	• Sniffing position is often best achieved in neutral position or using a shoulder roll
Epiglottis	Shorter, floppier, omega-shaped, angled over laryngeal inlet	• Larynx more cephalad (C3-4) than adults (C5-6) • May use Miller (straight blade to directly lift epiglottis) instead of Mac blade
Airway	Narrower and shorter trachea	• Smaller ETT needed • ↑ risk of endobronchial intubation • Higher airway resistance = ↑ work of breathing and risk of fatigue • More prone to obstruction
	↑ airway reactivity	• Laryngospasm more common (3x more likely in neonates)
	Narrow subglottic region	• ETT should always be carefully sized regardless of being cuffed/uncuffed to minimize occurrence of subglottic edema and postop stridor

PHYSIOLOGIC DIFFERENCES IN CHILDREN

System	Physiological changes	Implication/risks
Cardiovascular	Stiffer ventricles; CO is dependent on HR	• Difficulty increasing stroke volume to compensate for ↓ HR leading to ↓ BP
	↑ vagal tone Immature sympathetic nervous systems (<8 y/o)	• Typically ↓ HR in response to noxious stimuli (e.g. hypoxia, laryngoscopy) • (↓ HR is hypoxia until proven otherwise) • Pediatric bradycardia: *< 1 y/o: <100 bpm* *1-5 y/o: <80 bpm* *> 5 y/o: <60 bpm*
Pulmonary	↓ FRC	• Shorter time to hypoxia when apneic

	↑ O2 consumption/ metabolic rate	• ↑minute ventilation (↑ alveolar ventilation)
Hematological	↑ relative blood volume (neonate/infant)	• ↑ volume of distribution of medications in body = ↑ dose needed for induction • Absolute decrease in volume compared to adults requires more accurate fluid management *(see Fluid Management & Resuscitation: 4-2-1 rule)*
GI	Hepatic development (e.g. CYP450) may be incomplete (<1 y/o)	• ↓ degradation/excretion of active metabolites and ↓ protein binding = ↓ dose needed for maintenance infusion
Renal	↓ maximum solute load (<1 y/o)	• ↓ excretion of active metabolites • Typically use D5NS ± K+ or LR for maintenance fluids • Hypotonic solutions may ↑ risk of cerebral edema
Neurological	Varying stages of cognitive/behavioural development	• Caregiver calmness and distraction techniques are helpful when the child is anxious • Adolescents: ask about substance use and contraceptive use/possibility of pregnancy
	Variable response to medications	• ↑ BBB permeability = ↑ effects of certain medications (e.g. opioids) • ↑ MAC requirements

ETT SIZING

Canadian Pediatric Society guidelines:

Age	Uncuffed ETT size
< 1 year	3.0 - 3.5mm
1-2 years	3.5 - 4.0mm
> 2 years	(Age in years/4) + 4.0mm

✶ Cuff is 0.5mm, therefore subtract 0.5 from calculated value for cuffed ETT.
✔ Often manufacturers will include a black marker line to line up at the vocal cords which indicates appropriate depth of insertion. To estimate depth of ETT measured at teeth, take ETT size x 3.

Note: As a child's anatomic and physiological systems develop and mature, many of the following considerations will also change. For example, children > 1 y/o typically require much higher doses than adults to maintain anesthesia, but before that, they may require less. It is beyond the scope of this resource to comprehensively cover anesthetic considerations throughout the spectrum of pediatric development.

COMPLICATIONS & EMERGENCIES

LARYNGOSPASM

- This complication is more common in children than adults.
- Highest risk are infants 1-3 months old.

(See Airway management, intubation, and emergencies: Laryngospasm)

References:

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Basic pharmacology in anesthesia

Section reviewer: Jared Cohen
Senior reviewer: Denise Darmawikarta, MD
Staff reviewer: David Lagrotteria, MD

Knowledge-based objectives:
- *Explain the goals and phases of GA.*
- *Explain the following concepts as they relate to drugs administered via IV: half-time, therapeutic range, metabolism, redistribution, elimination, and target organ.*
- *Explain the concept of balanced anesthesia and its role in modern GA.*
- *Describe systematic mechanisms of increasing safety in the delivery of inhalation and IV drugs including labeling of syringes, needle recapping, use of needless systems, percent hypoxic anesthetic mixtures, etc.*

Essential Clinical Encounters objectives:
- *How can obesity impact the pharmacokinetics of certain anesthestic agents?*
- *Think how the use of neuromuscular blocking may be affected in certain neuromuscular diseases.*
- *In patients with advanced neuromuscular disease, how would their cardiorespiratory system be affected given neuromuscular blocking drugs?*

Skills objectives:
NA

GOALS OF ANESTHESIA

- Anxiolysis
- Amnesia
- Analgesia
- Akinesia (paralysis)
- Autonomic stability

PHASES OF ANESTHESIA

1. **Preparation**
   - Pre-op assessment and optimization
   - Anesthetic plan
   - Anxiolysis and analgesia
2. **Induction**
   - Pts are anesthetized (amnesia, analgesia, akinesia)
   - Management of airway
3. **Maintenance**
   - Maintenance of anesthesia and autonomic stability
4. **Emergence**
   - Reversal of anesthetic agents and awakening
5. **Recovery**
   - Monitoring of vitals, pain, adverse effects
   - Post-op care and follow-up

DEFINITIONS

Half-time: The time it takes to decrease a drug's concentration by half.
100% → 50% → 25% → 12.5% → 6.25% → etc.

Context-sensitive half-time: Half-time of a drug from steady-state after discontinuation; impacted by tissue redistribution; considered when delivering an infusion.
- Context-insensitive (half-time remains the same with prolonged infusion): remifentanil
- Significantly context-sensitive (half-time increases with prolonged infusion): fentanyl

Therapeutic range: The blood concentration of a drug that produces the desired effect. Dosing is often based on weight.
- **Total body weight:** Succinylcholine, propofol infusion
- **Lean body weight:** Opioids, propofol bolus
- **Ideal body weight:** Non-depolarizing NMBAs

Elimination: How drugs and metabolites are excreted.
- Water-soluble drugs are more easily excreted through urine/bile.

Distribution: The effect of IV drugs depend on relative perfusion of the organ. Drugs can also accumulate in tissues (e.g. fat) depending on dosage and duration.
- **Vessel-rich:** Heart, liver, kidneys, brain
- **Vessel-poor:** Skeletal muscle, adipose
- ↑ **tissue accumulation** = lipophilic, low protein binding, non-ionized
- ↓ **tissue accumulation** = hydrophilic, high protein binding, ionized
- Pts who are obese may have increased accumulation due to increased adipose tissue.

Target organ: The desired location of drug action.
- **Brain**: Premedication, induction agents
- **Muscle**: Paralytics

- **Liver / kidney**: Metabolism/degradation/excretion
- **Heart, vasculature**: Vasoactive drugs

Arm-brain circulation time: The time it takes from a drug injected into a peripheral IV to reach the brain and exert an effect.

Minimum alveolar concentration (MAC): The minimum alveolar concentration of an inhaled agent required to prevent movement in response to surgical stimuli in 50% of the population. Describes the potency of volatile anesthetic agents.

- MACs are additive (0.5 MAC sevoflurane + 0.7 MAC desflurane = 1.2 MAC)
- ED50 concentration measurement (e.g. at 1.3 MACs, ~95-99% of population will not
- respond)
- Inversely related to lipophilicity
- MAC needed to blunt autonomic response = 1.6

Factors increasing MAC	Factors decreasing MAC
• Drugs that increase central catecholamines (e.g. ephedrine, acute amphetamine intoxication) • Chronic EtOH misuse • Infants <6 months • Hyperthermia • HyperNa+ (in CNS) • Thyrotoxicosis	• Drugs that depress CNS (e.g. opioids, benzos, ketamine, α-2 agonists, IV local anesthetics) • Acute EtOH intoxication • Older age • Pregnancy • Hypothermia • Hypotension • Hypoxemia

PARALYTIC/NEUROMUSCULAR BLOCKING AGENTS (NMBAS)

Depolarizing NMBA: Non-competitive blocker of ACh at post-synaptic NMJ nicotinic receptors. Causes depolarization leading to fasciculations as part of mechanism of action.
- i.e. Succinylcholine

Non-depolarizing NMBA: Competitive blocker of ACh at post-synaptic NMJ nicotinic receptors. Does NOT cause depolarization of muscles during MoA.
- e.g. Rocuronium, vecuronium, pancuronium, (cis-)atracurium
- ↓ hepatic/renal function = ↑ duration of NMBA (except for (cis-)atracurium, see Quick Drugs Reference for details)

Train of four (TOF): Ratio of 4th:1st muscle twitch response on peripheral nerve (e.g. ulnar nerve using adductor pollicis).
- Ratio = 0: Complete paralysis
- Ratio <0.3: Sufficient paralysis (>90% blockade); reversal agents will not be effective
- Ratio >0.9: Sufficient recovery of muscle tone for extubation

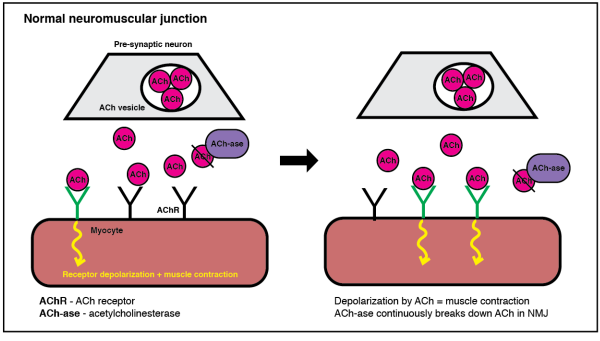
PARALYTICS AND NEUROMUSCULAR DISEASE
- Any cause of loss of muscle contraction can lead to increased post-junctional ACh receptors (e.g. crush/burn injury, UMN/LMN lesion, denervation, immobility, toxins).
- Adverse events of paralytics in these conditions include hyperK+, rhabdomyolysis, prolonged paralysis, respiratory complications, and autonomic instability.

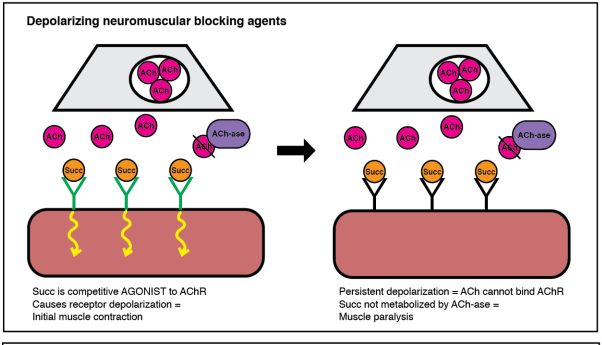
Examples of neuromuscular diseases and response to paralytics:

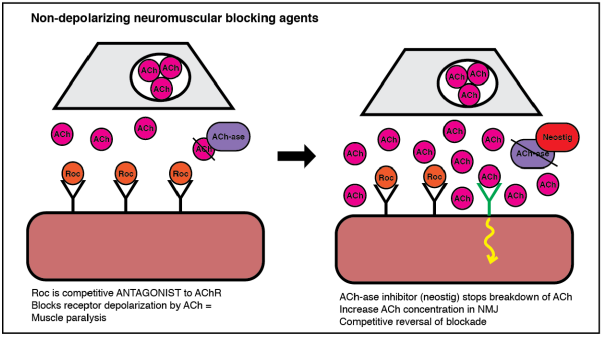
Neuromuscular disease	Depolarizing	Non-depolarizing
Diabetic neuropathy *Polyneuropathy of sensory, motor, and autonomic nerves*	✔	✔
Duchenne's/Becker's muscular dystrophy *Genetic lack of dystrophin leading to atrophy and fibrosis*	✘	↑ sensitivity
Multiple sclerosis *Loss of pre-junct myelin sheaths*	✷	✔
Myasthenia gravis *Antibodies against post-junct ACh-Rs*	↓ sensitivity	↑ sensitivity

✘ *Avoid use of drug*
✔ *No change in dosing required*
✷ *Cautious use in severe disease*

Figure 10: Neuromuscular junction in response to paralytics







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Quick Drug Reference

Drug name *Trade name*	
Common Uses in Anesthesia ✔	✔ Indications for usage of this drug, primarily limited in scope to its common usage by an anesthesiologist.
Significant Properties & Effects	• Effects or other notable properties of the drug.
Mechanism of Action	• Brief summary of how the drug causes its main effects.
Adverse Drug Effects	**CNS:** **CVS:** **RESP:** **GI/GU:** **MSK/DERM:** **OTHER:**
Cautions & Contraindications	• General cautions or contraindications for usage. • **Note**: No distinctions between cautions and relative/absolute contraindications are given as it is beyond the scope of this resource.
Onset (IV/PO)	Approximate onset of effect (when using this specific route of administration)
Duration (IV/PO)	Approximate duration of effect (when using this specific route of administration)
Metabolism	Primary location of drug metabolism
Dosing	Common indication: Dosing (for adults) given in mg or mcg. (Volatile anesthetics) Minimal alveolar concentration #

Disclaimer: This is not a comprehensive drug chart. Generalizations are made where possible to promote a basic framework of pharmacology and usage; ask your preceptor or see references and further readings about specific usages or situations encountered.

Note: Pediatric dosing for anesthetic drugs is weight-based and is beyond the scope of this resource. All dosing in these charts is given for general use in adult patients.

Knowledge-based objectives:

- *Identify IV drugs used in the induction, maintenance, and emergence of GA, including indications for use, mechanism of action, and common side effects.*
- *Identify inhalation anesthetic agents used in the induction and maintenance of GA, including mode of delivery, indications for use, mechanism of action, and common side effects.*

Essential Clinical Encounters objectives:

- *If a patient's condition raises concerns of cardiovascular instability intraoperatively, what adaptation of technique could you use in terms of selection of drugs?*
- *List the most common vasopressors. What are their specific features?*
- *Why might one be cautious of dexamethasone use for patients with diabetes?*

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ANXIOLYTICS

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Midazolam *Versed*	
Common Uses in Anesthesia ✔	✔ Anxiolysis, sedation, amnesia ✔ Induction or adjunct to general anesthesia ✔ Tx for seizures and status epilepticus
Significant Properties & Effects	• Short-acting benzodiazepine • Hypnotic, sedative, anticonvulsant, anxiolytic, amnesic • No effect on ICP, ↓ CNS blood flow
Mechanism of Action	• Benzodiazepine receptor agonist in CNS → enhances binding affinity of GABA to GABA receptor → CNS depression
Adverse Drug Effects	**CNS:** Post-op delirium/confusion (especially in elderly) **CVS:** Slight effects on ↓ BP **RESP:** ↓ RR (dose-dependent; especially in elderly, pts with COPD or OSA, or when given with opioids), hiccups
Cautions & Contraindications	• Elderly or pre-existing cognitive impairment • Concurrent opioid use or acute alcohol intoxication • COPD, OSA • Shock, ↓ BP • Acute narrow-angle glaucoma
Onset (IV)	2-3min
Duration (IV)	<2h
Metabolism	Hepatic
Dosing	Premedication (PO): 0.25-0.5 mg/kg (typical maximum 15mg) Premedication (IM): 0.07-0.08 mg/kg (typical maximum 5mg) Premedication (nasal spray): 0.2 mg/kg (pediatric pts) Premedication (bolus): 1-2mg IV Induction (bolus): 0.05-0.15mg/kg IV (dose reduced with increasing age, or given as co-induction agent) Sedation (bolus): 0.5-1mg IV, repeated

Lorazepam *Ativan*	
Common Uses in Anesthesia ✔	✔ Anxiolysis, sedation, amnesia ✔ Induction or adjunct to general anesthesia ✔ Tx for seizures and status epilepticus
Significant Properties & Effects	• Longer-acting benzodiazepine (compared to midazolam) • Hypnotic, sedative, anticonvulsant, anxiolytic, amnesic • No effect on ICP, ↓ CNS blood flow
Mechanism of Action	• Benzodiazepine receptor agonist in CNS → enhances binding affinity of GABA to GABA receptor → CNS depression
Adverse Drug Effects	**CNS:** Post-op delirium/confusion (especially in elderly) **CVS:** Slight effects on ↓ BP **RESP:** ↓ RR (dose-dependent; especially in elderly, pts with COPD or OSA, or when given with opioids), hiccups
Cautions & Contraindications	• Elderly or pre-existing cognitive impairment • Concurrent opioid use or acute alcohol intoxication • COPD, OSA • Shock, ↓ BP • Acute narrow-angle glaucoma
Onset (IV)	15-30min
Duration (IV)	6-8h
Metabolism	Hepatic
Dosing	Premedication (PO or sublingual): 1-4mg given 1-2h pre-op Premedication (bolus): 0.04mg/kg up to 4mg IV

INDUCTION AGENTS

Section reviewer: Yvgeniy Oparin
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Staff reviewer: Daniel Cordovani, MD

Propofol	
Common Uses in Anesthesia ✔	✔ Induction, sedation, maintenance of GA, monitored anesthesia care ✔ Total IV anesthesia (TIVA) ✔ Rescue medication: status epilepticus
Significant Properties & Effects	• ↓ ICP, ↓ BP = cerebral and cardioprotective • Anti-emetic effect • Synergistic effects when given together with opioids and benzodiazepines
Mechanism of Action	• Enhances binding of GABA to GABA receptor → CNS depression
Adverse Drug Effects	**CNS:** ↓ ICP **CVS:** ↓ BP (↓ CO, ↓ SVR) **RESP:** ↓ RR, apnea **OTHER:** Burning upon injection (can mix with lidocaine to help), propofol infusion syndrome
Cautions & Contraindications	• Significant chronic EtOH usage (may require higher dosing) or acute intoxication (may require lower dosing) • Shock • Severe hypotension • Severe CAD • Reduced LV ejection fraction (i.e. fixed CO)
Onset (IV)	<30s
Duration (IV)	5-10min
Metabolism	Hepatic
Dosing	Induction (bolus): 1-2.5mg/kg IV (dose reduced with increasing age or sicker pts) Sedation (infusion): 25-75mg/kg/min IV Maintenance (infusion): 100-200mcg/kg/min IV (dose reduced when combined with opioid)

Ketamine	
Common Uses in Anesthesia ✔	✔ Induction, sedation, maintenance of GA (especially for use in hypovolemic shock or cardiomyopathic pts (excluding ischemic heart disease), or pts with reactive airways) ✔ Tx status asthmaticus ✔ Analgesia; adjunct therapy for pain management
Significant Properties & Effects	• Sympathomimetic effects range of minimal to positive • (↑ BP, ↑ HR) on CVS • Bronchodilation • Attenuates acute tolerance to opioids • Dissociative anesthesia, emergence reactions (vivid dreams, illusions)
Mechanism of Action	• Depresses function in cortex and thalamus • Inhibition of excitatory NMDA receptor, inhibition of dorsal horn in spinal cord, and some effects on opioid receptors → analgesic effects • Indirect sympathomimetic effects by stimulating release of norepinephrine (can be attenuated with benzodiazepine)
Adverse Drug Effects	**CNS:** ↑ IOP, hallucinations, unpleasant vivid dreams, emergence delirium/confusion **CVS:** ↑ HR, ↑ BP **RESP:** ↑ respiratory secretions/saliva, laryngospasm
Cautions & Contraindications	• Prolonged shock/hypotension, critically-ill (pts with depleted catecholamine stores may experience myocardial depression, ↓ BP, ↓ CO) • Elderly pts, Hx of psychosis, post-op delirium • Conditions that cannot tolerate HTN (e.g. severe CAD, hemorrhagic stroke)
Onset (IV)	<30s
Duration (IV)	10-15min
Metabolism	Hepatic
Dosing	Induction (bolus): 1-2mg/kg IV Sedation and analgesia (bolus): 0.2-0.8mg/kg IV over 2-3min

Etomidate	
Common Uses in Anesthesia ✔	✔ Induction, short-term sedation (especially for use in hemodynamically-unstable pts such as trauma, hypovolemic shock, cardiovascular disease, ICU pts) ✔ Pts with ↑ ICP, reactive airway disease
Significant Properties & Effects	• Minimal cardiovascular depression compared with other induction agents (no effect on SNS) • ↓ICP, ↓cerebral metabolic rate
Mechanism of Action	• Enhances binding of GABA to GABA receptor → CNS depression
Adverse Drug Effects	**GI/GU:** PONV **MSK:** Myoclonus, hiccups **OTHER:** Adrenal suppression (may be significant when used as infusion; only transient effects when used as bolus), burning upon injection
Cautions & Contraindications	• Pre-existing adrenal suppression • Sepsis • Elderly pts
Onset (IV)	<30s
Duration (IV)	5-10min
Metabolism	Hepatic
Dosing	Induction (bolus): 0.2-0.6mg/kg IV

VOLATILE ANESTHETICS

Section reviewer: Ellen Connelly
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General properties of volatile anesthetics (*except nitrous oxide)*

General volatile anesthetic properties	
Common Uses in Anesthesia ✔	✔ Maintenance of general anesthesia
Significant Properties & Effects	• Vasodilatory effects
Mechanism of Action	• Uncertain • Potential location of action in spinal cord and CNS
Adverse Drug Effects	**CNS:** ↑ ICP **CVS:** ↓ BP **GI/GU:** N/V
Cautions & Contraindications	• PMHx/FHx of MH
Metabolism	NA

Sevoflurane	
Common Uses in Anesthesia ✔	✔ Inhaled anesthetic of choice for pediatric pts (due to pleasant smell)
Significant Properties & Effects	• Slower onset/offset time than desflurane • Sweet, pleasant smell • Bronchodilation
Adverse Drug Effects	**CVS:** ↓ HR **RESP:** Laryngospasm (less likely than with des/isoflurane) **GI/GU:** N/V **OTHER:** Compound A accumulation (nephrotoxic)
Onset (inhaled)	Rapid onset
Duration (inhaled)	<10min
Dosing	2.0 MAC

Desflurane	
Significant Properties & Effects	• Very fast onset/offset time of volatile anesthetics (due to very poor aqueous (blood) solubility) • Pungent smell, airway irritant
Adverse Drug Effects	**CVS:** Reflex tachycardia **RESP:** Bronchospasm, laryngospasm
Cautions & Contraindications	• Severe CAD • Severe asthma
Onset (inhaled)	Rapid onset
Duration (inhaled)	10min
Dosing	6.0 MAC

Isoflurane	
Significant Properties & Effects	• Slower onset/offset than sevo/desflurane • Highly lipophilic • Pungent smell, airway irritant
Adverse Drug Effects	**CVS:** Potentially coronary steal syndrome, reflex tachycardia **RESP:** Bronchospasm, laryngospasm
Cautions & Contraindications	• Severe CAD • Severe asthma
Onset (inhaled)	Rapid onset
Duration (inhaled)	<15min
Dosing	1.2 MAC

Nitrous Oxide	
Common Uses in Anesthesia ✔	✔ Used only as adjunct with other anesthetic agents or O2 ✔ Sedation, analgesia (e.g. dental, OB)
Significant Properties & Effects	• Very fast onset/offset time (due to very poor aqueous (blood) solubility) • No effect on BP (hemodynamically neutral) • Second gas effect (helps speed uptake of concurrently delivered gases due to ↑ partial pressure)
Mechanism of Action	• Uncertain • Potential location of action in spinal cord and CNS
Adverse Drug Effects	**CNS:** ↑ ICP **CVS:** ↑ HR, ↓ BP **RESP:** Pulmonary HTN, atelectasis **GI/GU:** N/V **OTHER:** Bone marrow toxicity, diffusion hypoxemia, diffusion into closed spaces (e.g. bowel, pleural space)
Cautions & Contraindications	• ↑ ICP • Shock, hypovolemia • Severe CAD • Anoxic administration • Pneumothorax, emphysema, air cysts, bowel obstruction • Eye and retina surgery (gas bubble expansion)
Onset (inhaled)	Immediate onset
Duration (inhaled)	Rapid off after discontinuation
Metabolism	NA
Dosing	104 MAC (Note: N2O is never used alone because it is a very weak agent.)

OPIOID ANALGESICS

Section reviewer: Gwen Lovsted
Senior reviewer: Russell Lenferna, MD
Staff reviewer: Rafik Bolis MB BCh

General properties of opioids

General opioid properties	
Common Uses in Anesthesia ✔	✔ Gold standard for nociceptive or inflammatory pain relief ✔ ↓ SNS response and ↓ cough reflex to laryngoscopy and intubation
Significant Properties & Effects	• Synergistic effects when given with volatile anesthetics (↓MAC requirements), propofol, or benzodiazepines • Analgesic effect is equivalent between opioids if given in appropriately-converted doses • Causes histamine release from mast cells
Mechanism of Action	• Opioid receptor agonist (mu, kappa, delta receptors) • Acts on both peripheral nerves and neurons in spinal cord/brain to cause hyperpolarization of cell → ↓ neuronal excitability → ↓ transmission of painful sensations to CNS • Modulation of perception of pain
Adverse Drug Effects	**CNS:** Sedation **CVS**: ↓ BP, ↓ HR (dose dependent) **RESP**: ↓ RR, apnea **GI/GU**: N/V, constipation/paralytic ileus, urinary retention **MSK/DERM**: Opioid-induced muscle rigidity, smooth muscle contraction, pruritus **OTHER**: Opioid-induced hyperalgesia (chronic or high-dose use)
Cautions & Contraindications	• Shock, ↓ BP • Acute/severe asthma, respiratory disease, OSA • ↓ RR or apnea • GI obstruction/ileus
Metabolism	Most often hepatic (CYP450 2D6, 3A4); may produce active or inactive metabolites. (See specific opioid charts.)

Morphine	
Common Uses in Anesthesia ✔	✔ Post-op analgesia ✔ IV (e.g. PCA) and neuraxial analgesia
Significant Properties & Effects	• Low lipophilicity; slower penetration of BBB
Mechanism of Action	• Active metabolite of morphine (M6G) is full mu opioid receptor agonist
Cautions & Contraindications	• Renal disease (↑ accumulation of active metabolites)
Onset (IV)	10-20min
Duration (IV)	2-5h
Metabolism	Hepatic → active (M6G) and inactive (M3G) metabolites
Dosing	Post-op analgesia, PACU (bolus): 2-4mg IV q5-10min prn; maximum 10mg Post-op analgesia, wards (bolus): 2-10mg IV/SC q4h prn

Hydromorphone *Dilaudid*	
Common Uses in Anesthesia ✔	✔ Post-op analgesia ✔ IV (e.g. PCA) and epidural analgesia
Significant Properties & Effects	• 5x more potent that morphine
Cautions & Contraindications	• Renal disease (accumulation of nephrotoxic and active metabolites)
Onset (IV)	<30min
Duration (IV)	2-4h
Metabolism	Hepatic → active and inactive metabolites
Dosing	Post-op analgesia, PACU (bolus): 0.2-0.6mg IV q5-10prn; maximum 2mg

Fentanyl	
Common Uses in Anesthesia ✔	✔ Intermediate-acting analgesic ✔ Adjunct for induction of GA ✔ Adjunct to spinal/epidural anesthesia ✔ PCA ✔ Management of chronic pain (e.g. patch, nasal spray, lozenges)
Significant Properties & Effects	• High lipophilicity → faster penetration of BBB, accumulation in tissues • Long context-sensitive half-time • 100x more potent than morphine
Onset (IV)	<5min
Duration (IV)	30-60min
Metabolism	Hepatic → inactive metabolites
Dosing	Adjunct to GA (bolus): 2-6mcg/kg IV Peri-op analgesia (bolus): 25-50mcg IV q15-30min Peri-op analgesia (infusion): 0.5-5mcg/kg/hr IV

Remifentanil	
Common Uses in Anesthesia ✔	✔ Ultra short-acting analgesia ✔ Adjunct to GA ✔ Monitored anesthesia care sedative infusion
Significant Properties & Effects	• High lipophilicity; faster penetration of BBB • Short context-sensitive half-time (does not accumulate in tissues due to pathway of metabolism) • 100-200x more potent than morphine
Onset (IV)	1-2min
Duration (IV)	5-10min
Metabolism	Nonspecific tissue and RBC esterase → inactive metabolites
Dosing	Adjunct to GA (infusion): 1mcg/kg IV bolus follow by 0.02-0.1mcg/kg/min IV Sedation (infusion): 0.05-0.3mcg/kg/min IV

Meperidine *Demerol*	
Common Uses in Anesthesia ✔	✔ Post-op shivering
Significant Properties & Effects	• 1/10th as potent as morphine • Not used for analgesia
Adverse Drug Effects	**CNS**: Anxiety, seizures (normeperidine toxicity), serotonin syndrome **MSK/DERM**: Myoclonus
Cautions & Contraindications	• Renal disease (accumulation of neurotoxic metabolites) • MAOIs, TCAs, SSRIs, SNRIs (may precipitate serotonin syndrome)
Onset (IV)	5-10min
Duration (IV)	2-4h
Metabolism	Hepatic → active metabolites (normeperidine)
Dosing	Post-op shivering (bolus): 25mg IV

Sufentanil	
Common Uses in Anesthesia ✔	✔ Intermediate-acting analgesia/adjunct to GA ✔ Labour analgesia
Significant Properties & Effects	• High lipophilicity; faster penetration of BBB • 500x more potent than morphine
Onset (IV)	3-5min
Duration (IV)	20-40min
Metabolism	Hepatic → inactive metabolites
Dosing	Adjunct to GA (bolus): 1-8mcg/kg IV

NON-OPIOID ANALGESICS

Section reviewer: Gwen Lovsted
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Acetaminophen *Tylenol*	
Common Uses in Anesthesia ✔	✔ OTC mild-moderate pain management (e.g. fever, arthritis, cramps, headaches, MSK aches/flares)
Significant Properties & Effects	• Analgesic, antipyretic
Mechanism of Action	• Uncertain • May inhibit COX2 and increase pain threshold • May inhibit endogenous pyrogens in hypothalamus
Adverse Drug Effects	**GI/GU:** Constipation, liver failure **MSK/DERM:** Rash, Stevens-Johnson syndrome
Cautions & Contraindications	• Active heavy alcohol use • Hepatic disease, renal disease
Onset (PO)	<1h
Duration (PO)	4-6h
Metabolism	Hepatic
Dosing	Pain (PO): 325-650mg q4-6h; maximum 3250mg/day Pain (IV): 650mg q4h; maximum 4g/day

Ibuprofen *Advil / Motrin*	
Common Uses in Anesthesia ✔	✔ OTC mild-moderate pain management (e.g. fever, arthritis, cramps, headaches, MSK aches/flares)
Significant Properties & Effects	• Analgesic, antipyretic, anti-inflammatory • NSAID
Mechanism of Action	• Non-selective COX-1 and COX-2 inhibitor prevents conversion of AA to PGs and TXA
Adverse Drug Effects	**CVS:** HTN, CHF, MI **GI/GU:** Dyspepsia, constipation, GI bleeding, ulcer, perforation, AKI **MSK/DERM:** Rash, Stevens Johnson Syndrome **OTHER:** ↑ bleeding time, stroke
Cautions & Contraindications	• Asthma • Renal disease, heart failure, liver disease • ACEIs, diuretics, additional NSAIDs, aspirin • Hx of PUD, GI bleeding, or perforation • Hx of bariatric surgery or any enteric anastomosis
Onset (PO)	30-60min
Duration (PO)	4-6h
Metabolism	Hepatic
Dosing	Pain, OTC (PO): 200-400mg q4-6h; maximum 1200 mg/day. Pain, prescription (high dose) (PO): 400-800mg q6h prn; maximum 3200 mg/day.

Ketorolac *Toradol*	
Common Uses in Anesthesia ✔	✔ Acute pain (<5d) that requires opioid-level management
Significant Properties & Effects	• Analgesic, antipyretic, anti-inflammatory • No sedation or anxiolysis • NSAID
Mechanism of Action	• (Essentially selective) COX-1 inhibitor prevents conversion of AA to PGs and TXA
Adverse Drug Effects	**CVS:** Edema, HTN, CHF, MI **GI/GU:** Dyspepsia, constipation, GI bleeding, ulcer, perforation, AKI **MSK/DERM:** Rash, pruritus, Stevens Johnson Syndrome **OTHER:** ↑ bleeding time, thrombocytosis, stroke
Cautions & Contraindications	• IBD • Asthma • Renal disease, heart failure, liver disease • ACEIs, diuretics, additional NSAIDs, aspirin • Hx of PUD, GI bleeding, or perforation • Hx of bariatric surgery or any enteric anastomosis • Current/suspected hemorrhage/high risk of bleeding • Neuraxial administration
Onset (IV)	<30min
Duration (IV)	4-6h
Metabolism	Hepatic
Dosing	*Maximum duration <5 days. Not for use in chronic pain.* Acute pain (IV): 15-30mg once or 30mg q6h; maximum 120mg/day (though evidence suggests therapeutic ceiling at 15mg) Acute pain (IM): 60mg once or 30mg q6h; maximum 120mg/day Acute pain (PO): (only as transition from IV/IM) 20mg + 10mg q6h prn; maximum 40mg/day

LOCAL ANESTHETICS

Section reviewer: Ellen Connelly
Senior reviewer: Janice Yu, MD
Staff reviewer: Rafik Bolis MB BCh

Note:
- Percentages on local anesthetics are calculated as mg/mL; maximum doses should be calculated as maximum mL as well as mg. E.g. 1% lidocaine = 0.01g/mL = 10mg/1mL
- Epinephrine is often added to promote local vasoconstriction and retention of the drug, thus allowing higher maximum doses than when used without epinephrine.
  - For a 70kg person:
    - Maximum without epi: 4.5mg/kg → 315mg → 31.5mL max
    - Maximum with epi: 7mg/kg → 490mg → 49mL max

(See also Obstetrical Anesthesia: Local Anesthetic Systemic Toxicity.)

Lidocaine *Xylocaine*	
Common Uses in Anesthesia ✔	✔ Local anesthetic for minor procedures (e.g. dental, subcut) ✔ Adjunct in general and regional anesthesia ✔ Injected prior to or mixed with propofol to reduce burning sensation on propofol injection ✔ Tx of status epilepticus
Significant Properties & Effects	• Class 1B anti-arrhythmic used for treating ventricular arrhythmias • Not used in spinal anesthesia due to risk of causing transient neurological symptoms (pain, paresthesia)
Mechanism of Action	• Reversible blockade of voltage-gated Na+ channels of peripheral nerves → prevents activation and consequently Na+ influx → no depolarization, no AP • Differential nerve block occurs (preferentially effects smaller diameter and myelinated nerves first; therefore, usually sensory loss before motor loss)
Adverse Drug Effects	**CNS:** Headache, seizures **CVS:** ↓ BP, ↓ HR, bradyarrhythmia, heart block **RESP:** ↓ RR **MSK/DERM:** Paresthesias **OTHER:** Local anesthetic systemic toxicity
Cautions & Contraindications	• Severe hepatic disease • Shock, ↓ BP, ↓ HR • Heart block
Onset & Duration	Varies based on method of administration. Generally, onset of a few minutes, duration of a few hours.
Metabolism	Hepatic
Dosing	Maximum without epi: 4.5mg/kg Maximum with epi: 7mg/kg

Bupivacaine *Marcaine*	
Common Uses in Anesthesia ✔	✔ Anesthetic for regional and neuraxial anesthesia
Significant Properties & Effects	• Slower onset, longer duration of action, and more potent than lidocaine • Available in different baricities (drug density relative to CSF) to promote desired intrathecal spread
Mechanism of Action	• Reversible blockade of voltage-gated Na+ channels of peripheral nerves → prevents activation and consequently Na+ influx → no depolarization, no AP • Differential nerve block occurs (preferentially effects smaller diameter and myelinated nerves first; therefore, usually sensory loss before motor loss)
Adverse Drug Effects	**CNS:** Headache, seizures **CVS:** ↓ BP, ↓ HR, bradyarrhythmia, heart block **RESP:** ↓ RR **MSK/DERM:** Paresthesias **OTHER:** High spinal, local anesthetic systemic toxicity
Cautions & Contraindications	• Severe hepatic disease • Arrhythmias (which restrict CO) • Heart block
Onset & Duration	Varies based on method of administration. Generally, onset of a few minutes, duration of a few hours.
Metabolism	Hepatic
Dosing	Maximum without epi: 2.5mg/kg Maximum with epi: 3mg/kg

PARALYTICS

Section reviewers: Jared Cohen, Misha Virdee
Senior reviewer: Dillon Horth, MBChB
Staff reviewer: David Lagrotteria, MD

Rocuronium

Common Uses in Anesthesia ✔	✔ Non-depol NMBA ✔ Modified RSI (at higher doses)
Significant Properties & Effects	• May be reversed with sugammadex
Mechanism of Action	• Competitive antagonist of ACh in post-synaptic nicotinic receptors in NMJ • Prevents ACh-mediated depolarization of muscle • Effects reversible by inhibiting ACh-esterase = ↓ breakdown of ACh = ↑ concentration of ACh in NMJ outcompetes NMBA
Adverse Drug Effects	**CVS:** Variable effect on BP and HR **RESP:** ↑ pulmonary vascular resistance **MSK/DERM:** Pruritus, rash **OTHER:** Injection site pain, anaphylaxis (NMBs are the most common cause of anaphylaxis during general anesthetic)
Cautions & Contraindications	• Neuromuscular disease, trauma/burn pts (requires dose adjustment to avoid hyperK+) • Pts with a known difficult airway
Onset (IV)	1.5-2min (Modified RSI: 1min)
Duration (IV)	30-40min (Modified RSI: >60min)
Metabolism	Hepatic
Dosing	Paralytic (bolus): 0.6mg/kg IV + 0.1-0.2mg/kg IV prn Modified RSI (bolus): 1.2mg/kg IV + 0.1-0.2mg/kg IV prn

Succinylcholine	
Common Uses in Anesthesia ✔	✔ Fast-acting depolarizing NMBA ✔ Paralytic for rapid sequence induction
Significant Properties & Effects	• Structure is 2 ACh molecules joined by methyl group • Depolarization of cells → ↑ extracellular K+ • Causes histamine release • No reversal agent available
Mechanism of Action	• Agonist of AChR in post-synaptic nicotinic receptors • Phase I block (desensitization block): Binding to AChR causes initial depolarization and contraction of muscle but is not metabolized by ACh-esterase = prolonged receptor binding = inactivated receptor to subsequent ACh-mediated depolarization • Phase II block: Mechanism not completely understood; presynaptic mechanism may ↓ synthesis and ↓ mobilization of ACh
Adverse Drug Effects	**CNS:** ↑ ICP, ↑ IOP **CVS:** Bradyarrhythmias/bradycardia (vagal stimulation of muscarinic receptors in SA node, especially prominent in children), sinus arrest (rare). Repeated doses increases risk of CVS effects. **RESP:** Bronchospasm, ↑ secretions **GI/GU:** Myoglobinuria, ↑ intragastric pressures **MSK/DERM:** Fasciculations, myalgias, rhabdomyolysis **OTHER:** Transient or pathological hyperK+, MH, prolonged paralysis (PCD), anaphylaxis (NMBAs are the most common cause of anaphylaxis during GA)
Cautions & Contraindications	• Abdominal infection • Glaucoma, ↑ ICP, ↑ IOP • Severe hepatic/renal disease • PMHx/FHx of MH or PCD • HyperK+, severe burns/trauma, spinal injury, severe upper motor neuron disease, neuromuscular disease • Pts with a known difficult airway
Onset (IV)	<1min
Duration (IV)	<10min
Metabolism	Plasma enzymatic (plasma pseudocholinesterase)
Dosing	Phase I block (bolus): 1-2mg/kg IV Phase II block: Not used in routine clinical practice

Cis-atracurium *Nimbex*	
Common Uses in Anesthesia ✔	✔ Non-depol NMBA ✔ Pts with severe renal and/or hepatic failure ✔ ICU pts requiring paralysis to aid ventilation (i.e. ARDS)
Significant Properties & Effects	• Non-enzymatic plasma hydrolysis is ideal for pts with renal/ hepatic disease
Mechanism of Action	• Competitive antagonist of ACh in nicotinic post-synaptic nicotinic receptors in NMJ • Prevents ACh-mediated depolarization of muscle • Effects reversible by inhibiting ACh-esterase = ↓ break-down of ACh = ↑ concentration of ACh in NMJ outcom-petes NMBA
Adverse Drug Effects	**CVS:** Variable effect on BP, arrhythmias, ↓ HR **RESP:** Bronchial secretions, wheezing **MSK/DERM:** Flushing, rash **OTHER:** Anaphylaxis (NMBs are the most common cause of anaphylaxis during general anesthetic)
Cautions & Contraindications	• Neuromuscular disease, trauma/burn pts (requires dose adjustment to avoid hyperK+) • Pts with a known difficult airway
Onset (IV)	5-7min
Duration (IV)	45-70min
Metabolism	Plasma hydrolysis (Hoffman elimination) >> renal clearance
Dosing	Intubation (bolus): 0.1-0.2mg/kg IV Maintenance (bolus): 0.03 mg/kg IV Maintenance (infusion): 1-2mcg/kg/min IV

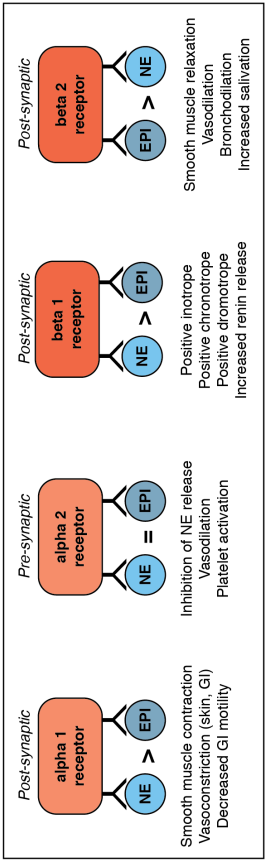
RESCUE:

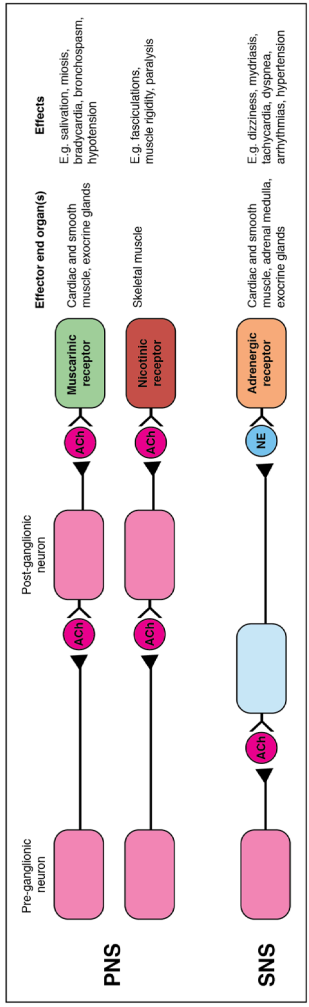
Dantrolene *Ryanodex*	
Common Uses in Anesthesia ✔	✔ Rescue medication for malignant hyperthermia ✔ Tx for neuroleptic malignant syndrome, thyroid storm
Significant Properties & Effects	• Suppresses excitation–contraction coupling without interfering with resting or transmission of action potentials
Mechanism of Action	• Antagonist to ryanodine receptor prevents release of Ca2+ from sarcoplasmic reticulum • ↓ free intracellular Ca2+ = ↓ excitation-contraction coupling = ↓ ATP usage and metabolic demand
Adverse Drug Effects	**CNS:** Dizziness, sedation **RESP:** Dyspnea **GI/GU:** N/V, dysphagia, diarrhea **MSK/DERM:** Muscle weakness, flushing
Cautions & Contraindications	• Severe hepatic disease • Severe cardiac disease • COPD • *When used as tx of MH, dantrolene does not have an absolute contraindication.*
Onset (IV)	Immediate
Duration (IV)	30-120min
Metabolism	Hepatic
Dosing	Malignant hyperthermia: 2.5mg/kg IV bolus repeated as required until stable + 0.25mg/kg·h IV for 24h afterwards *Must be reconstituted with sterile water.*

VASOACTIVE & AUTONOMIC DRUGS

Section reviewer: Ellen Connelly
Senior reviewer: Jacob Salituri, MD
Staff reviewer: Kevin Latchford, MD

Figure 11/12: Brief overview of the functions and receptors of the autonomic nervous system





Ephedrine	
Common Uses in Anesthesia ✔	✔ Intra-op hypotension (temporizing tx) without tachycardia
Significant Properties & Effects	• Sympathomimetic effects • ↑ HR, ↑ SV, ↑ CO, ↑ peripheral vasoconstriction • ↑ myocardial demand
Mechanism of Action	• Stimulates release of granules of norepinephrine at sympathetic nerve endings → indirect α/β adrenergic stimulation • May have small amount of direct adrenergic effect • Tachyphylaxis may occur with repeat doses (catecholamine depletion)
Adverse Drug Effects	**CNS**: Dizziness, tremor **CVS**: ↑↑ BP, palpitations, tachyarrhythmias
Cautions & Contraindications	• Ischemic heart disease (increases myocardial demand) • Phenylephrine often preferred to ephedrine in L&D (effects are more favorable for fetal acid-base status)
Onset (IV)	<1min
Duration (IV)	10min
Metabolism	Unmetabolized renal excretion
Dosing	Intra-op hypotension (bolus): 5-10mg IV prn to maximum 50mg

Common dilution in OR (not typically used outside of OR or L&D):
(in a 10mL syringe) 50mg/1mL ephedrine + 9mL NS = 5mg/mL ephedrine solution.

Phenylephrine	
Common Uses in Anesthesia ✔	✔ Intra-op hypotension (temporizing tx) ✔ Hypotension from spinal/epidural (often used in L&D due to better effects than ephedrine on fetal acid-based status)
Significant Properties & Effects	• Pure α drug (i.e. essentially no β-adrenergic activity unless very high doses) • ↑↑ venous and arterial vasoconstriction = ↑ SVR • May induce reflex bradycardia (2° to vagal response, baroreceptor-mediated) • Variable effect on CO (depends on preload/afterload as it has no chronotropic/inotropic effects)
Mechanism of Action	• Direct α1-adrenergic receptor agonist
Adverse Drug Effects	**CVS**: Arrhythmia, ↓ CO, ↑↑ BP, R/L ventricular failure, myocardial demand ischemia, peripheral ischemia **RESP**: Pulmonary edema
Cautions & Contraindications	• Heart block, ↓ HR • Ischemic heart disease, PAD • ↑ ICP (hemorrhage, TBI)
Onset (IV)	<1min
Duration (IV)	10-15min
Metabolism	Hepatic
Dosing	Intra-op hypotension (bolus): 50-200mcg IV q10-15min prn Intra-op hypotension (infusion): 0.1-1mcg/kg/min IV titrated to BP

To dilute:
(100mL bag NS) 10mg/1mL phenylephrine + 100mL NS = 100mcg/mL phenylephrine solution.

(250mL bag NS) 10mg/1mL phenylephrine + 250mL NS = 40mcg/mL phenylephrine solution.

Epinephrine	
Common Uses in Anesthesia ✔	✔ Cardiac arrest/resuscitation ✔ Anaphylaxis/bronchospasm, status asthmaticus ✔ Unstable/severe bradycardia ✔ Severe hypotension/shock (norepinephrine more commonly used since less arrhythmogenic) ✔ Adjunct when using local anesthetics (vasoconstriction slows systemic absorption of anesthetic)
Significant Properties & Effects	• ↑ HR, ↑ SV, ↑ vasoconstriction • ↑ bronchodilation, ↓ mucosal edema • ↓ mast cell/basophil inflammatory mediator release
Mechanism of Action	• Direct α1 and non-selective β adrenergic agonist
Adverse Drug Effects	**CNS**: Cerebral hemorrhage **CVS**: Palpitations, arrhythmias, ↑↑ BP **RESP**: Pulmonary edema **OTHER**: Infusion site necrosis
Cautions & Contraindications	• HTN, arrhythmias, ischemic heart disease, cardiomyopathy • Glaucoma • Autonomic dysreflexia
Onset (IV)	<1min
Duration (IV)	5-10min
Metabolism	Hepatic
Dosing	Anaphylaxis (bolus): 0.3-0.5mg q5-10min IM or 0.05-1mg IV/IO. Cardiac arrest/resus (bolus): 1mg IV/IO q3-5min until ROSC Status asthmaticus (bolus): 0.3-0.5mg q20min SQ to maximum 3 doses Hypotension/shock (infusion): 0.05-2mcg/kg/min, titrate to desired MAP q10-15min

Norepinephrine *Levophed*	
Common Uses in Anesthesia ✔	✔ Hypotension from undifferentiated/refractory shock (1st line especially for septic/distributive shock) ✔ Cardiac arrest/resuscitation
Significant Properties & Effects	• At low dose, β1 effect predominant = ↑ HR, positive inotrope and chronotrope • At higher dose, α1 effect predominant = ↑ peripheral vasoconstriction = ↑ SVR • ↑ myocardial demand
Mechanism of Action	• Direct α1 and β1 adrenergic receptor agonist
Adverse Drug Effects	**CVS**: ↓ HR (reflex, β1 effects don't fully compensate), arrhythmia, ↑↑ BP, peripheral ischemia **GI/GU**: Urinary retention **OTHER**: Infusion site necrosis (from extravasation)
Cautions & Contraindications	• Severe hypoxia/hypercapnia (sensitizes myocardium to unstable arrhythmias) • Hypotension due to low blood volume (unless temporizing until adequate fluid resuscitation)
Onset (IV)	1-2min
Duration (IV)	1-2min
Metabolism	Hepatic
Dosing	Hypotension, septic shock (infusion): 0.01-3mcg/kg/min IV Cardiac arrest/resus (infusion): initial 8-12mcg/min IV, maintenance 2-4mcg/min IV

Vasopressin *Vasostrict*	
Common Uses in Anesthesia ✔	✔ Hypotension from septic/distributive shock (2nd line added to norepinephrine for refractory shock) ✔ Cardiac arrest (refractory pulseless VTach/VFib, PEA/asystole) ✔ GI variceal hemorrhage
Significant Properties & Effects	• Positive inotrope • Vasoconstriction = ↑ SVR, ↑ MAP • ↑ water retention
Mechanism of Action	• Synthetic arginine vasopressin receptor agonist • V1 receptor contracts vascular smooth muscle • V2 receptor increases water resorption in renal tubules
Adverse Drug Effects	**CVS**: ↓ CO, arrhythmias, coronary artery vasoconstriction **RESP**: Pulmonary edema, bronchoconstriction **OTHER**: Water intoxication syndrome (HypoNa+), infusion site necrosis (from extravasation)
Cautions & Contraindications	• Ischemic heart disease • Renal disease
Onset (IV)	15min
Duration (IV)	Within 20min of infusion discontinuation
Metabolism	Hepatic >> renal
Dosing	Hypotension, septic/distributive shock (infusion): 0.04units/min IV; maximum 0.07units/min Cardiac arrest (bolus): 40units in 40mL

Esmolol	
Common Uses in Anesthesia ✔	✔ Intra/post-op tachycardia or HTN ✔ SVT and A-fib/A-flutter ✔ Acute MI/ACS ✔ Intubation (in lieu of opioids to blunt SNS response)
Significant Properties & Effects	• Class II antiarrhythmic (rhythm control) • ↓ HR, ↓ SVR, ↓ CO, ↓ BP
Mechanism of Action	• Short-acting selective β1-blocker • ↓ adrenergic stimulation of myocardium/pacemaker = ↓ AVN conduction, ↓ HR, negative inotrope
Adverse Drug Effects	**CNS**: Headache, dizziness **CVS**: Hemodynamic compromise (dose-dependent) **RESP**: Bronchospasm **OTHER**: Injection site reaction
Cautions & Contraindications	• 2nd/3rd degree heart block, severe bradycardia • Severe/prolonged hypotension (e.g. cardiogenic shock) • Asthma/COPD
Onset (IV)	1-2min
Duration (IV)	20-30min
Metabolism	RBC esterases
Dosing	Intra/post-op tachycardia or HTN: 0.5-1mg/kg bolus IV over 30s + 50-200 mcg/kg/min infusion, titrate as needed

Labetalol	
Common Uses in Anesthesia ✔	✔ Hypertensive emergency ✔ Pre-eclampsia/eclampsia, hypertensive emergency of pregnancy (SBP >160, DBP >110 longer than 15min)
Significant Properties & Effects	• ↓ SVR, ↓ BP • No significant change in CO, no reflex tachycardia
Mechanism of Action	• Selective α1-blocker, nonselective β-adrenergic blocker (1:7 α:β blockade effects)
Adverse Drug Effects	**CNS**: Headache, dizziness **CVS**: LV heart failure, orthostatic hypotension **RESP**: Bronchospasm
Cautions & Contraindications	• CHF, latent cardiac insufficiency • 2nd/3rd degree heart block, severe bradycardia • Severe/prolonged hypotension (e.g. cardiogenic shock) • Asthma/COPD
Onset (IV)	5-10min
Duration (IV)	4hr
Metabolism	Hepatic
Dosing	Hypertensive emergency/pre-eclampsia (bolus): 5-20mg IV over 2min, increase dosage q10min by 40-80mg as needed; maximum 300mg/day.

Hydralazine	
Common Uses in Anesthesia ✔	✔ Hypertensive emergency ✔ Pre-eclampsia/eclampsia, hypertensive emergency of pregnancy (SBP >160, DBP >110 for longer than 15min)
Significant Properties & Effects	• ↓ SVR, ↑ CO, ↑ HR (reflex)
Mechanism of Action	• Multiple mechanisms of smooth muscle relaxation; does not interact with adrenergic/cholinergic receptors • Alters Ca2+ metabolism → induces non-contractile state • Arteriolar >> venous effects (effects on coronary, cerebral, splanchnic, and renal vessels greater than in skin, muscle)
Adverse Drug Effects	**CNS**: Headache, dizziness **CVS**: Angina, palpitations, reflex tachycardia (may be combined with β-blocker) **OTHER**: Drug-induced SLE
Cautions & Contraindications	• Angina/myocardial ischemia, ischemic heart disease • Cerebrovascular disease, stroke • SLE
Onset (IV)	5-15min
Duration (IV)	2-4h
Metabolism	Hepatic
Dosing	Hypertensive emergency (bolus): 20-40mg IV q4-6h prn Pre-eclampsia/eclampsia (bolus): 5-10mg IV + repeat q20min prn

Nitroglycerin	
Common Uses in Anesthesia ✔	✔ Perioperative HTN ✔ Myocardial ischemia (angina, MI), ventricular failure (CHF) ✔ GI variceal hemorrhage ✔ Uterine relaxation (for delivery of retained placenta)
Significant Properties & Effects	• ↑ peripheral vasodilation = ↓ preload = ↓ BP • Venous >> arteriole effects • ↓ myocardial demand • No risk of cyanide toxicity (unlike nitroprusside)
Mechanism of Action	• Forms free NO → ↑ cGMP in smooth muscle → ↓ intracellular Ca2+ → smooth muscle relaxation
Adverse Drug Effects	**CNS**: Headache, fatigue/weakness, syncope **CVS**: ↓↓ BP, ↑ HR (reflex) **OTHER**: Flushing
Cautions & Contraindications	• Shock, untreated hypovolemia • Right-sided MI (highly preload dependent), constrictive pericarditis, tamponade, cardiomyopathy • Use of phosphodiesterase-5 inhibitors (e.g. Viagra) • ↑ ICP
Onset (IV)	Immediate
Duration (IV)	3-5min
Metabolism	Hepatic >> RBCs, vascular walls
Dosing	Perioperative HTN (infusion): 0.1-5mcg/min IV + titrate dosing q3-5min to response

REVERSAL AGENTS AND ANTICHOLINERGICS

Section reviewers: Jared Cohen, Misha Virdee
Senior reviewer: David Parsons, MD
Staff reviewer: David Lagrotteria, MD

Neostigmine	
Common Uses in Anesthesia ✔	✔ Reversal of non-depolarizing NMBAs ✔ Tx of myasthenic crisis
Significant Properties & Effects	• Does not cross BBB = ↓ cholinergic effect in CNS • Global increase of ACh (both nicotinic and muscarinic junctions) = ↑ PNS; therefore must use antimuscarinic to prevent adverse effects • *Does not reverse succinylcholine.*
Mechanism of Action	• ACh-esterase inhibitor = ↑ACh concentrations in NMJ = ACh overcomes competitive inhibition by non-depolarizing NMBAs
Adverse Drug Effects	**CNS:** Seizures, confusion, coma **CVS:** ↓ HR, ↓ BP, AV block **RESP:** Bronchospasm, ↓ RR, ↑ salivation/bronchial secretions **GI/GU:** N/V, ↑ urination/defecation frequency **MSK/DERM:** Muscle spasms **OTHER:** Cholinergic crisis (↑↑↑ PNS)
Cautions & Contraindications	• Epilepsy • Asthma • Bradycardia • GI or urinary obstruction
Onset (IV)	5min
Duration (IV)	55-75min
Metabolism	Hepatic >> plasma esterases
Dosing	Reversal of NMBA: neostigmine 0.05mg/kg up to 5mg IV + (an anticholinergic, usually glycopyrrolate 0.01mg/kg IV)

Atropine	
Common Uses in Anesthesia ✔	✔ Prevention of cholinergic crisis during reversal of non-depolarizing NMBAs (though usually glycopyrrolate preferred due to fewer CNS effects) ✔ Antisialagogue ✔ Heart block, bradycardia
Significant Properties & Effects	• ↑ HR • Bronchodilation, ↓ secretions/salivation • Crosses BBB
Mechanism of Action	• Competitive antagonist of ACh at muscarinic receptors • Global anticholinergic (i.e. antimuscarinic) = ↓ PNS
Adverse Drug Effects	**CNS:** Confusion, anxiety, ↑ IOP, mydriasis, blurred vision, hallucinations **CVS:** ↑↑ HR, arrhythmias **GI/GU:** Constipation, urinary retention **MSK/DERM:** Flushing
Cautions & Contraindications	• HTN, arrhythmias, CAD • GI or urinary obstruction • Myasthenia gravis • Glaucoma
Onset (IV)	Immediate
Duration (IV)	1-2h
Metabolism	Hepatic > renal clearance
Dosing	Bradycardia (bolus): 0.5mg IV Reversal of NMBA (bolus): (neostigmine 0.05mg/kg) + atropine 0.015mg/kg IV

Glycopyrrolate	
Common Uses in Anesthesia ✔	✔ Prevention of cholinergic crisis during reversal of non-depolarizing NMBAs (preferred due to fewer CNS effects) ✔ Antisialagogue ✔ Bradycardia, high PNS tone
Significant Properties & Effects	• ↑ HR • Bronchodilation, ↓ secretions/salivation • Does not cross BBB
Mechanism of Action	• Competitive antagonist of ACh at muscarinic receptors • Global anticholinergic (i.e. antimuscarinic) = ↑ PNS
Adverse Drug Effects	**CNS:** Confusion, anxiety, ↑ IOP, mydriasis, blurred vision, hallucinations **CVS:** ↑↑ HR, arrhythmias **GI/GU:** Constipation, urinary retention **MSK/DERM:** Flushing
Cautions & Contraindications	• HTN, arrhythmias, CAD • GI or urinary obstruction • Myasthenia gravis
Onset (IV)	<1min
Duration (IV)	2h
Metabolism	Hepatic > renal clearance
Dosing	Reversal of NMBA (bolus): (neostigmine 0.05mg/kg) + glycopyrrolate 0.01mg/kg IV Antisialogogue (bolus): 4mcg/kg IV (typically 0.2-0.4mg IV)

Sugammadex	
Common Uses in Anesthesia ✔	✔ Elective reversal of rocuronium or vecuronium, limited primarily by cost. Currently only used electively if unable to adequately reverse with neostigmine. ✔ Emergency reversal of rocuronium or vecuronium (i.e. can't intubate, can't oxygenate)
Significant Properties & Effects	• *Does not reverse other non-depolarizing NMBAs or succinylcholine.*
Mechanism of Action	• Structure forms complexes with rocuronium and vecuronium = inactivation of NMBAs • ↓ concentration of free NMBAs in NMJ = ↓ blockade
Adverse Drug Effects	**CVS:** ↓↓ HR, ↓↓ BP (potential anaphylactic reactions with high doses) **OTHER:** Injection site pain, ↑ PTT/INR (transient effect lasting up to 1h), ↓ effectiveness of hormonal contraceptives (lasting 7d), difficulty in re-paralyzing with rocuronium/vecuronium in next 24h
Cautions & Contraindications	• Severe renal, cardiac disease • *When used as rescue reversal agent, sugamammadex does not have an absolute contraindication.*
Onset (IV)	2-3min
Duration (IV)	<24h
Metabolism	Unmetabolized renal excretion
Dosing	Profound blockade, rescue (bolus): 16mg/kg IV Deep blockade (<2 twitches) (bolus): 4mg/kg IV Standard reversal (>2 twitches) (bolus): 2mg/kg IV

POST-OPERATIVE NAUSEA/VOMITING

Section reviewer: Gwen Lovsted
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Staff reviewer: Kevin Latchford, MD

Dexamethasone *Decadron*	
Common Uses in Anesthesia ✔	✔ PONV prophylaxis (give any time after induction) ✔ Reduce airway edema/obstruction
Significant Properties & Effects	• Potent, long-acting synthetic corticosteroid
Mechanism of Action	• Possible location of action in brainstem chemoreceptive trigger zone
Adverse Drug Effects	*ADEs are highly dose-dependent as corticosteroids are extremely versatile drugs. For PONV prophylaxis dosage:* **CVS:** ↑ HR **MSK/DERM:** Pruritus **OTHER:** Hyperglycemia (transient, usually not clinically significant)
Cautions & Contraindications	• Poorly-controlled DM/impaired glucose tolerance • Glaucoma, ocular/periocular infection • Immunosuppressed pts (e.g. systemic fungal infection) (though most studies have shown no increase in wound infection with one dose of dexamethasone)
Onset (IV)	2h
Duration (IV)	3-5d
Metabolism	Hepatic
Dosing	PONV prophylaxis (bolus): 4-10mg IV

Ondansetron *Zofran*	
Common Uses in Anesthesia ✔	✔ PONV prophylaxis (give ~30min before end of surgery)
Mechanism of Action	• Serotonin (5-HT3) receptor antagonist in brainstem chemoreceptor trigger zone
Adverse Drug Effects	**CNS:** Headache **GI/GU:** Constipation, diarrhea, urinary retention **MSK/DERM:** Pruritus **OTHER:** Serotonin syndrome, tardive dyskinesia
Cautions & Contraindications	• QT prolongation
Onset (IV)	<30min
Duration (IV)	9h
Metabolism	Hepatic
Dosing	PONV prophylaxis (bolus): 4-8mg IV

Dimenhydrinate / *Gravol*	**Diphenhydramine** *Benadryl*
Common Uses in Anesthesia ✔	✔ 2nd/3rd line agents for PONV (typically associated with motion-sickness)
Mechanism of Action	• Competitive antagonist of histamine H1 receptor • Central anticholinergic effects
Adverse Drug Effects	**CNS:** Headache, dizziness, sedation, blurred vision **CVS:** ↑ HR **RESP:** Thickened bronchial secretions **MSK/DERM:** Flushing, dry mouth, rash
Cautions & Contraindications	• HTN, arrhythmias, CAD • Asthma, chronic pulmonary disease • ↑ IOP, glaucoma • GI/GU obstruction, prostatic hyperplasia • Neonates, young children • Elderly, pts with cognitive impairment
Onset (IV)	5min
Duration (IV)	4-6h
Metabolism	Hepatic
Dosing	PONV prophylaxis (bolus): 25-50mg IV

Metoclopramide *Maxeran*	
Common Uses in Anesthesia ✔	✔ PONV/aspiration prophylaxis (give ~30min before induction or emergence) ✔ DM gastroparesis
Significant Properties & Effects	• Pro-gastrokinetic agent • ↑ lower esophageal tone
Mechanism of Action	• Dopamine H2 receptor antagonist in brainstem chemoreceptor trigger zone • Sensitize tissues to ACh and ↑release of ACh from myenteric plexus
Adverse Drug Effects	**CNS:** Headache, drowsiness, fatigue **CVS:** Fluid retention **OTHER:** Akathisia, tardive dyskinesia, neuroleptic malignant syndrome
Cautions & Contraindications	• HTN, CHF • Epilepsy • GI hemorrhage, obstruction, perforation • Parkinson's disease, hx of extrapyramidal symptoms (e.g. tardive dyskinesia)
Onset (IV)	1-3min
Duration (IV)	1-2h
Metabolism	Hepatic
Dosing	PONV prophylaxis (bolus): 10-20mg IV

MISCELLANEOUS

Section reviewer: Lauren Riehm
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Staff reviewer: Kevin Latchford, MD

Amiodarone	
Common Uses in Anesthesia ✔	✔ Ventricular arrhythmias ✔ Cardiopulmonary resuscitation
Significant Properties & Effects	• Class III antiarrhythmic • Contains iodine
Mechanism of Action	• Blocks myocardial K+ channels → slows depolarization → prolongs refractory period → depresses automaticity • Also has effects on Na+/Ca2+ channels, β receptors
Adverse Drug Effects	*Most toxicities occur only in chronic use.* **CNS:** Peripheral neurotoxicity **RESP:** Pulmonary toxicity/fibrosis **GI/GU:** Hepatic toxicity **OTHER:** Thyroid toxicity, electrolyte abnormalities
Cautions & Contraindications	• ↓ HR, ↓ BP, cardiogenic shock • Severe sinus bradycardia or 2nd/3rd degree heart block without pacemaker, QT prolongation • Hepatic disease • Interstitial lung disease • Thyroid dysfunction • Iodine allergy
Onset (IV)	Minutes
Duration (IV)	Variable
Metabolism	Hepatic
Dosing	Cardiac arrest (bolus): 300mg IV/IO + 150mgmg IV/IO as per ACLS guidelines Arrhythmia with intact circulation (bolus): 150mg IV over 10 minutes + 150mg IV q10min as needed

Magnesium sulfate	
Common Uses in Anesthesia ✔	✔ Eclampsia treatment and prophylaxis ✔ Torsades de pointes, paroxysmal SVT
Significant Properties & Effects	• Vasodilation • Stabilizes cardiac myocytes • Provides fetal neuroprotection
Mechanism of Action	• Uncertain; likely multifactorial • Altered Ca2+ channels = ↓ smooth muscle contractility, ↑ vasodilation (e.g. coronary, cerebral, uterine) • ↓ ACh release = ↓ neuromuscular transmission
Adverse Drug Effects	**CNS:** Headaches **CVS:** Heart block, ↓ BP, ↓ PVR, cardiac arrest **MSK/DERM:** Weakness **OTHER:** Coagulopathy, prolongation of neuromuscular blockade, magnesium toxicity
Cautions & Contraindications	• Heart block • Renal disease
Onset (IV)	Immediate
Duration (IV)	30min
Metabolism	Renal
Dosing	Eclampsia: 4-6g IV loading dose over 5 min + 1-2g/h IV infusion; maximum 40g/24h. Recurrent seizures are treated with further 2g boluses. Eclampsia, seizure (bolus): 1g IM/IV Torsades de pointes (infusion): 1-2g diluted in 10ml D5W over 15min IV/IO

Oxytocin *Pitocin*	
Common Uses in Anesthesia ✔	✔ Initiation/improvement of contractions for medical indications ✔ Prophylaxis and tx for postpartum bleeding/hemorrhage
Significant Properties & Effects	• Peptide structure very similar to ADH (may lead to fluid retention) • Tachyphylaxis can occur in pts receiving oxytocin infusion for labor augmentation
Mechanism of Action	• Binds to oxytocin receptors on myometrium of uterus • ↑ intracellular Ca2+ = ↑ contraction, ↑ tone, ↑ frequency
Adverse Drug Effects	**CVS:** ↓ BP, PVCs/arrhythmias, cardiovascular collapse (when given as rapid IV bolus) **MSK/DERM:** Uteroplacental hypoperfusion, uterine spasm/ rupture **OTHER:** Water intoxication (hypoNa+) • Fetus: ↓ HR, ↓ O2, PVC/arrhythmias
Cautions & Contraindications	• For improvement of labour: Any contraindication to vaginal delivery (e.g. significant cephalopelvic disproportion, high risk of uterus rupture, unfavourable fetal presentation), hx of complicated L&Ds • Pre-eclampsia (may have unpredictable response)
Onset (IV)	<1min
Duration (IV)	<1h
Metabolism	Hepatic
Dosing	Postpartum hemorrhage: 10 units IM after delivery of the placenta Postpartum hemorrhage: 5 units IV slow push over 1-5min + maintenance infusion of 10 units/h; maximum 40 units Postpartum hemorrhage (infusion): 20-40 units/L in non-hydrating solution; maximum 40 units

- Note: Carbetocin (*Duratocin*)Longer-acting uterotonic drug compared with oxytocin with similar mechanism of action
- Used for the prevention of uterine atony and postpartum hemorrhage following c-section under anesthesia
- Postpartum hemorrhage, prophylaxis: 100mcg (single dose only)

Notes: