Welcome to the UMass PICU! We want to provide you with a guidebook on how the PICU works and a basic understanding of some PICU topics (fluids, sedation, ventilators). We also included clinical scenarios you may encounter while in the PICU. This is not meant to be all encompassing, but rather as an initial guide to help you along the way. The PICU is an amazing place with interesting cases and lots of learning. We hope you all enjoy your time spent here!

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Introduction to the PICU

Who's Who in the PICU and Their Jobs

Welcome to the UMass PICU! As residents, you are an important part of the PICU. This is one of the major rotations during residency where you develop a variety of skills that can be applied to your career goals. Even if you are not interested in intensive care, you will learn alot from this rotation. In the PICU, we are all a big team and help each other in order to provide the best care for our sickest patients. It is important to know who your teammates are and how they contribute.

PICU Nurses: Listen to the nurses. I repeat...listen to them! They are amazing nurses who have been working in the ICU for a long time (some have been in the PICU for 10+ years)! They are valuable assets when you are starting off and have questions. Get to know them and befriend them. They know their patients and will let you know when something is wrong.

Pharmacy (aka ATP): Ann is another valuable resource in the PICU. She works most days and will be present during rounds. She will go through all the medications that are listed in the MAR and can make any recommendations for your patients. You can call/walk into her office/page her with any questions you may have about medications.

PICU NP (Lauren Fortier): Lauren is a wonderful addition to the PICU team. She works mostly Mondays, Wednesdays and Thursdays as an extra staff member. She helps with a variety of tasks, including but not limited to admissions and direct patient care, procedures, social conundrums (PAs, ordering home oxygen and supplies, patient forms) and support for residents in general.

Respiratory Therapists (RTs): There are many respiratory therapists that rotate through the PICU. Some of them are pediatric specialists and are knowledgeable when it comes to vent settings and respiratory care for the younger patients. You can always ask them any questions and have them explain ventilator settings. RTs work during the day and night, so there is always someone to help you out.

Attendings: Last, but definitely not least are all the PICU attendings. Their schedule is located on the big calendar in the resident room. Sometimes they stay on for a few days or sometimes they work for only one day at a time. They are here for teaching and helping to support us, along with patient care of course! They want the best for residents and are great educators!

The Resident Flow

Weekdays:

Morning Sign-Out (7:00am)

- Arrive at 7:00am promptly for morning sign-out
    - The overnight resident will be very happy if you show up on time!
- There will be two residents during the day and one resident overnight
- Patients will be divided between the two daytime residents
    - You may choose which patients you want
    - This is really decided between the residents that are working

Pre-Round (7:30am - 8:00am)

- After sign-out, you can look up your patients on EPIC and review overnight events
- Nursing sign out occurs around 7:00am
    - Typically residents can wait until after nursing sign-out to talk with them about patients and concerns
- If you have a very sick patient, you should be evaluating that patient at the bedside immediately after sign-out
    - Check in with the nurse on the earlier side
    - If patient is acutely decompensating, you can call for backup (attendings, other senior residents, etc)
- Evaluate your other patients and perform exams, check vitals and I/Os, talk with families briefly if they have questions
- If you run out of time before morning conferences, you may evaluate and exam patients afterwards

Morning Conferences (8:00am - 9:00am)

- You are expected to attend all scheduled morning conferences
- If there is an acute decompensation or patients needs that are being addressed, you will be excused for conference
    - However, please make every effort to attend

Team Rounds (9:00am - end of rounds)

- Exam all patients before team rounds
- Team rounds include: residents, nurses, pharmacy, Lauren (on days she is present), attendings, and family members when applicable
- Always find the nurses first and ask if they are ready to round

- Most of the time, the team will round outside of the room where the patient is located and invite family members to join
    - There are always exceptions!!!
- Residents will present patients and the plan for the day
- If there are any questions about the plan, you can ask the attending during rounds and have discussions
- DON'T FORGET THE CHECKLIST
- Attendings will often teach during rounds, so pay attention even if it is not your patient
- While one resident is presenting, the second resident should be writing orders and on the computer
- When computers are available, both residents will have their own computer workstations to help with the workflow

Following Rounds (Afternoon, typically after 12:00pm)

- Have lunch!
- Follow up on any tasks discussed during rounds (consults, labs/orders, imaging)
- Check in with nurses and patients as needed
- Update any families that were not present during rounds
- Notes, notes and more notes
- Get transfers, admissions and/or discharges ready to go
- If time is available, attendings can have teaching sessions and PICU related lectures → just ask them if they're available!
    - Simulation sessions are also possible and are a great learning tool for disaster planning

Evening Sign-Out (6:00pm)

- Night resident will arrive at 6:00pm promptly
- Sign out your patients → Make sure to include nighttime tasks/follow-ups, disaster planning, etc

Nights:

Evening Sign-Out (6:00pm)

- Receive sign out from day team
- Check in with patients and evaluate them
- Nursing sign out is around 7:00pm. Check in with the night nurse

Overnight (6:00pm - 7:00am)

- Complete any overnight tasks and follow up on any results
- Check numbers overnight

- Overnight Rounds
    - Informal rounds with the nurses should occur sometime between 8:00pm-9:00pm
    - Resident's should go through the nighttime checklist, review daytime events, discuss the night plan or any overnight events (MRIs, travel, medication timing, etc)
- Attendings will call in the beginning of the night to run the list and answer any questions
    - This typically occurs between 9:00pm - 10:00pm
    - They will either call by phone or go on the remote video service
- Attendings may stay in-house if there is an unstable patient, but mostly will go home
    - They are available 24/7 - PLEASE do not be afraid to contact them with any questions or concerns, even in the middle of the night
- Lauren, our PICU NP, will stay until 10pm on Monday, Wednesday and Thursday
- Complete any admissions overnight
- For Monday to Thursday night, you do not have to write any notes (except admissions)
- For Friday night, you are responsible for writing all the notes for the patients starting after midnight

Morning Sign-Out (7:00am)
- Sign-Out to day team

Weekends (24 hour shifts):
Morning Sign-Out (8:00am)
- Sign-Out happens later on weekends because there are no morning conferences
- Overnight resident will run through any overnight events and new admissions
- If there are any unstable patients, please check in on them first and check in with the nurses for any needs
- Run through charts and numbers

Team Rounds (9:00am)
- On Saturdays, Sundays and Mondays, the overnight resident will stay and present all the patients for rounds
- Rounds will typically start around 9am
- Pharmacy and the PICU NP will not be present for rounds during the weekends
- The overnight resident should be leaving around 12pm AT THE LATEST given work hours

Following Rounds/Afternoon (~12:00pm to evening)
- Same as weekdays!
- Follow up on consults, tasks, imaging, labs, etc

- Perform any admissions, discharges, transfers
- Some attendings will perform teaching if time is available
- Depending on the day, the attendings will leave sometime in the afternoon but are available if needed

Evening (~8:00pm - morning)

- After nursing shift change, it is a good idea to check in with the nurses and have quick "rounds" with them
    - Review nighttime plans, change any orders, disaster planning with nursing, answer any questions about the patients
- Review nighttime numbers (vitals, I/Os) and complete any nighttime tasks
- After midnight, you can start notes on your patients
    - The overnight resident on weekends (Friday night, Saturday night, Sunday night) is responsible for writing all the notes for the next day
    - If a patient is admitted before midnight, they will still require a progress note for the next day (DIFFERENT FROM THE REGULAR FLOOR)
- If you are able to get some rest, always check in with the nurses before you go to the call room to follow up on any needs/questions

Surgery Rounds:

****This was no longer happening during COVID, but may restart in the future****

Weekdays (Around 5a - 6a)

- When there are surgery/trauma patients admitted to the PICU, the surgery team will round in the morning with the overnight PICU resident.
- For surgery rounds, the overnight resident will go through the patient presentation (overnight events, labs, vitals, plan) for the surgeons.
- Surgeons will relay any additional plans/recommendations for the day

Weekends (Around 6a - 8a)

- Weekends can be more varied with timing of surgery rounds
- Same concept as weekdays applies

Education

PICU Curriculum

Goal: To have different "themed" weeks and review common PICU cases that resident's may encounter during their time in the PICU. This standardized curriculum should cover all the important topics that resident's should learn in critical care.

The educational curriculum will combine in-person lectures given by attendings, "hands-on" and simulation sessions, and online lectures on OpenPeds.

	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1 **Cardiology**		PICU Lecture 11a-12p	PICU Lecture 11a-12p	Skills Session and Simulation 11a-12p	
Week 2 **Respiratory**		PICU Lecture 11a-12p	PICU Lecture 11a-12p	Skills Session and Simulation 11a-12p	
Week 3 **Neurology**		PICU Lecture 11a-12p	PICU Lecture 11a-12p	Skills Session and Simulation 11a-12p	
Week 4 **Shock & Trauma**		PICU Lecture 11a-12p	PICU Lecture 11a-12p	Skills Session and Simulation 11a-12p	

OpenPeds Curriculum

The UMass PICU team has a channel on OpenPeds (called UMass PICU) which contains lectures on different PICU topics to supplement resident education. These videos should be used in conjunction with in-person lectures and simulation sessions.

- Please create an account on OpenPeds using your "Umassmemorial.org" email account
- There are 5 different sections on OpenPeds:
    - Cardiology
    - Respiratory
    - Shock
    - Neurology
    - Miscellaneous
- Within each section, there are core lectures and supplementary lectures
    - Every week, residents should choose one section to learn
    - The expectation is that the residents watch all the core lectures from every section
    - The supplementary lectures are optional, but are still useful for increasing resident's medical knowledge on critical care topics

SECTION	CORE LECTURES	SUPPLEMENTS
Cardiology	1. Cardioversion 2. Defibrillation 3. Cardiac Arrest	
Respiratory	1. Oxygen Metabolism 2. Pediatric Airway Anatomy 3. Respiratory Distress 4. Common Respiratory Problems 5. Critical Asthma 6. Non Invasive Ventilation 7. Mask Ventilation 8. Intro to Mechanical Ventilation 9. Modes of Mechanical Ventilation 10. Airway Equipment for Intubation	● Non Invasive Ventilation: Practical Issues ● Non Invasive Ventilation: Complications ● Non Rebreather Mask and Non Vent Bag ● Capnography ● Management of Intubated Asthmatic ● Clinical Exam Findings in Asthma

Neurology	1. Intro to TBI 2. Status Epilepticus 3. Status Epilepticus Algorithm 4. Cerebral Edema DKA 5. Management of DKA	● Brain Death Examination
Shock	1. Shock	

Attending Lectures

Lectures should be given to residents during their PICU rotation by the attending physicians. These lectures are supplementary to the online OpenPediatric lectures. The lectures can be relevant to the weekly theme (respiratory, cardiology, shock, neurology) or they can be chosen individually by the attendings based on the needs of the residents.

Common PICU Attending Lecture Topics	
● Sedation ● Ventilators ● Fluids/Transfusions ● DKA ● Shock ● Bronchiolitis ● Status Asthmaticus ● TBI	● ARDS ● Status Epilepticus ● Pressors ● Toxicology ● Death and Dying - Ethics ● Post Resuscitation Care ● Arrhythmias ● Acid/Base

Simulation and Skill Sessions

The PICU team hosts weekly simulation sessions and “hands on” sessions that occur mostly on Thursdays. These sessions should be relevant to the designated weekly theme.

Simulation Cases

- Each simulation case should last about 15 minutes with another 15 minutes of time for debriefing
- Cases should include topics from cardiology/arrhythmia, neurology, shock and respiratory

Skill Sessions

- There should be about 30 minutes of “hands on” practice either before or after the simulation session
- Skill sessions will include hands-on practice techniques
    - Examples include AEDs, code carts, ventilators, central lines

PICU Prep

During PICU Prep, residents should be attending as many skills sessions and lectures as possible. Residents should also set up different learning opportunities as outlined below. The expectation is that residents reach out to different people at the beginning of the rotation and set up meetings themselves. You will be expected to keep track of your educational opportunities and give it to the PICU attendings at the end of your rotation for sign-off. Please reach out to the PICU attendings and/or pediatric chiefs if you are having any difficulty setting up opportunities.

- Anesthesia - Dr. Peter Foley
    - Contact anesthesia and Dr. Foley to set up a few days to spend with anesthesia. This is a great opportunity to practice BVM and sometimes intubation.
- Dr. Neal Tyrrell
    - Please reach out to Neal to attend patient safety meetings. These typically occur on Monday afternoons. Please confirm with Neal when you may be able to attend.

Admissions

Admissions can occur at any time during the PICU. All admissions need to be approved by the attending physician.

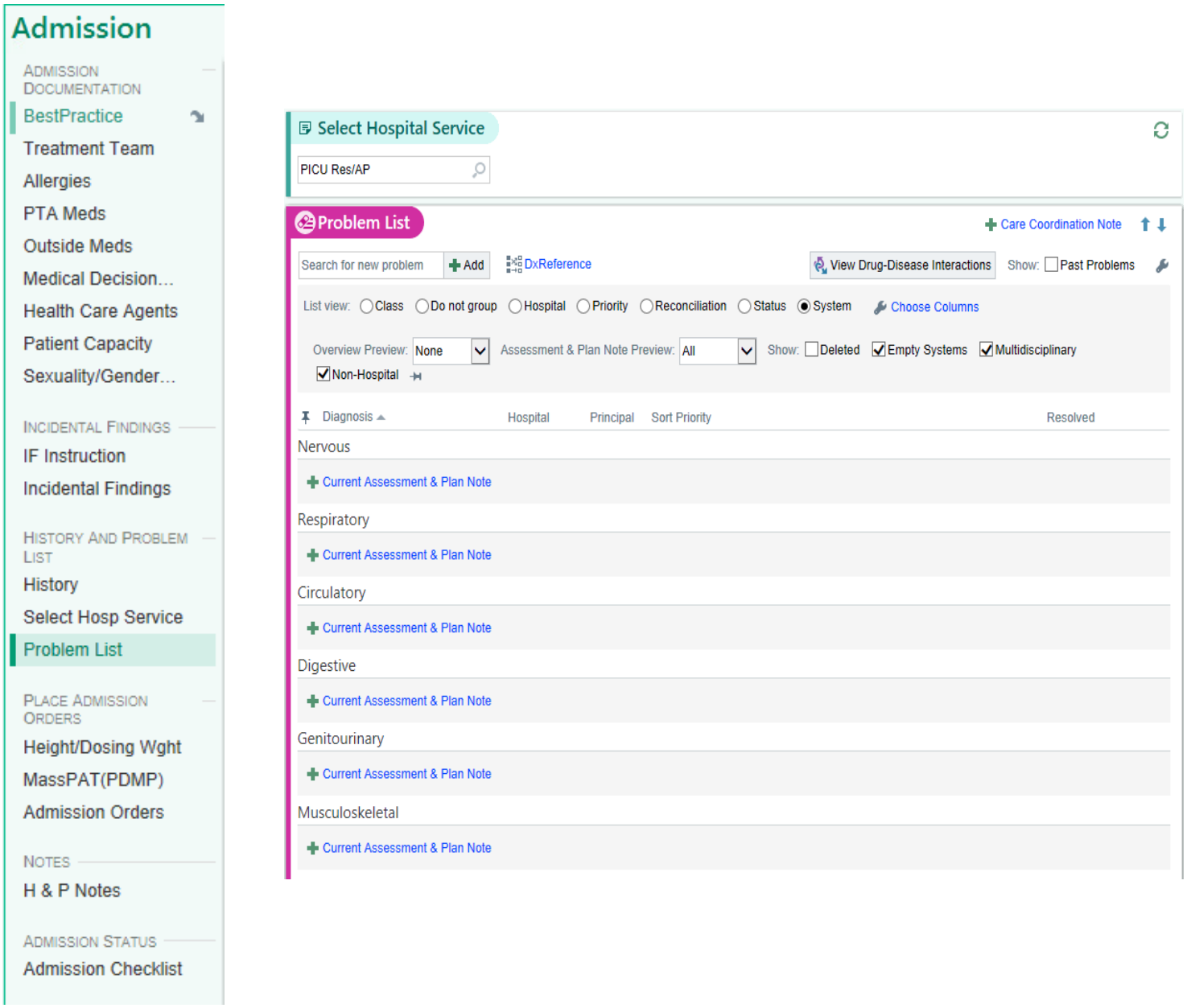
In general, the ED or admitting team will call the attending physician and perform sign-out. The attending will determine if the admission is appropriate and accept the patient. The attending will then call the resource nurse and determine the bed situation and alert the nurses of the admission. The attending will call the resident and give a brief sign-out about the new admission. The resident will need to go to the ED or the pediatric floor and evaluate the patient. If the patient is unstable, the resident should travel with the patient to the PICU if needed. Otherwise, the resident can return to the PICU and alert the nurses that the patient is ready to be transferred. Residents must perform a thorough history and physical examination for all patients.

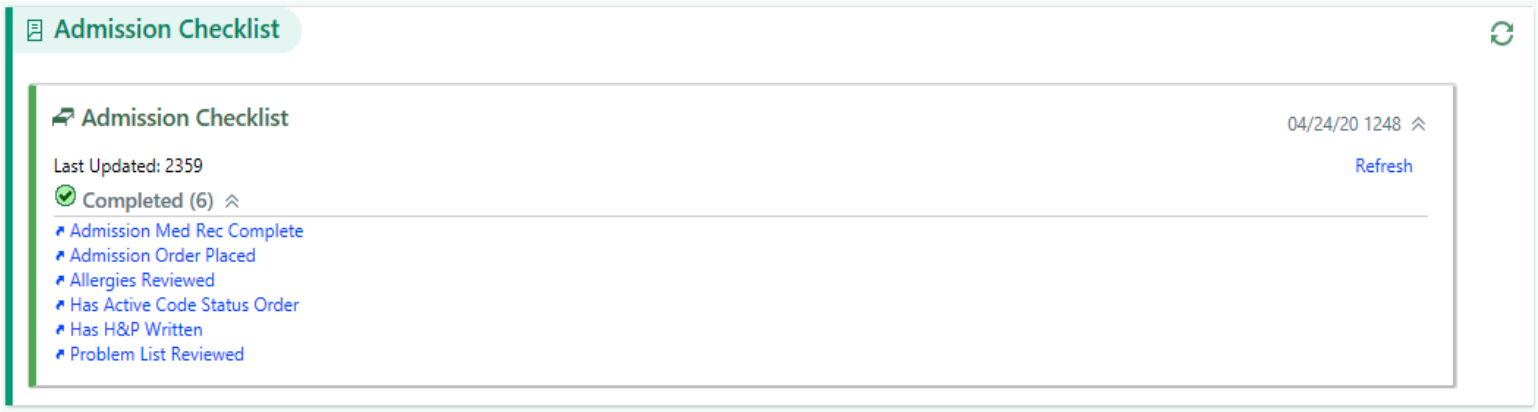
Admissions (not including 5east transfers) will be from the ED and the OR.

1. ED Admissions
    a. ED admissions are the most common
    b. You will get sign out from the PICU attending about ED patients
    c. You need to go to the ED and can gather further history from the ED residents and/or family
    d. Notes:
        i. Residents are required to write H&Ps for every single admission.
        ii. For overnight admissions: If the H&P is written before midnight, residents are required to write a progress note after midnight for the next day. If the H&P is written after midnight, residents do NOT need to write an additional progress note for the next day.
2. OR Admissions
    a. Occasionally the PICU will receive a post-op patient for admission
    b. The surgeon will alert the PICU attending who will alert the resident
    c. Residents typically receive sign out for surgery residents or NP/PAs
    d. Anesthesia should also give sign out especially if the patient is arriving intubated. You need to know what type of sedation they received
    e. Notes:
        i. Residents need to write a full H&P for OR admissions even if the surgeon has written an H&P

EPIC Admission Tips

- Follow the Admission tab on EPIC as to not miss anything
- Please review the following tabs on admission
    - Allergies, Meds (PTA and outside), Problem List, Admission Orders
- You can use the Admission Checklist as a guide to make sure nothing is missing
- All admissions need a code sheet printed and signed at the bedside
    - Nurses will sometimes print this out and ask you to sign
    - To find the Code Sheet:
        - Go to Clinical Resources Tab → Clinica References → Micromedex
        - Once on Micromedex, click on the Calculators Tab
        - Under Calculators, go to ACLS/PALS Guidelines
        - Type in the weight of the patient and hit submit
        - Type in the name of the patient and then print
        - Sign the sheet and give to the nurses to place at bedside
- Problem List
    - This tab under the admission set is very useful for notes
    - You need to add any problems that the patient has for admission
    - Then you can write your assessment and plans under each system (Nervous, Respiratory, Cardiac)
    - This is will be pulled into your notes (H&P and progress notes)
    - In order to pull it into the notes, you can use the DotPhrase ".lastprobap"
    - This is not required, but very helpful for residents especially those cross covering on weekends
- Depending on the admission, there are different order sets for admission orders. Common order sets include DKA, TBI, Bronchiolitis, Sedation and Pain for Mechanically Intubated, Status Asthmaticus


Admission
ADMISSION DOCUMENTATION
BestPractice
Treatment Team
Allergies
PTA Meds
Outside Meds
Medical Decision...
Health Care Agents
Patient Capacity
Sexuality/Gender...
INCIDENTAL FINDINGS
IF Instruction
Incidental Findings
HISTORY AND PROBLEM LIST
History
Select Hosp Service
Problem List
PLACE ADMISSION ORDERS
Height/Dosing Wght
MassPAT(PDMP)
Admission Orders
NOTES
H & P Notes
ADMISSION STATUS
Admission Checklist
Select Hospital Service
PICU Res/AP
Problem List
Care Coordination Note
Search for new problem
Add
DxReference
View Drug-Disease Interactions
Show: Past Problems
List view: Class Do not group Hospital Priority Reconciliation Status System
Choose Columns
Overview Preview: None
Assessment & Plan Note Preview: All
Show: Deleted Empty Systems Multidisciplinary
Non-Hospital
Diagnosis
Hospital
Principal
Sort Priority
Resolved
Nervous
Current Assessment & Plan Note
Respiratory
Current Assessment & Plan Note
Circulatory
Current Assessment & Plan Note
Digestive
Current Assessment & Plan Note
Genitourinary
Current Assessment & Plan Note
Musculoskeletal
Current Assessment & Plan Note


Admission Checklist
Admission Checklist
04/24/20 1248
Last Updated: 2359
Refresh
Completed (6)
Admission Med Rec Complete
Admission Order Placed
Allergies Reviewed
Has Active Code Status Order
Has H&P Written
Problem List Reviewed

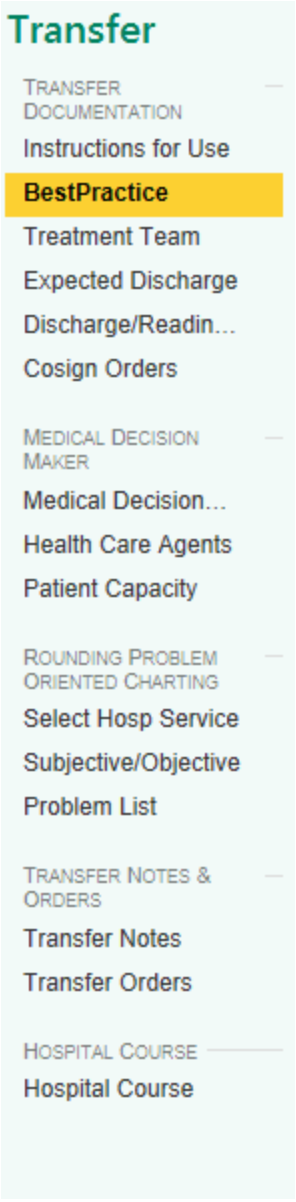
Transfers

Patients can come to the PICU as transfers from 5east. Patients are often transferred out of the PICU once stable and sent to 5east.

From 5East to PICU:

If a patient decompensates and becomes unstable on the general pediatric floor, they will need to be transferred to the PICU.

- PICU residents will get notified about an unstable patient. Most of the time the residents on 5East will give you a heads up for "watchers" on the floor before they become unstable. Watchers can be listed on the resident white board in the PICU.
- Once notified of an unstable patient, you should evaluate the patient on the floor. The 5east resident should call the 5east attending to determine if the patient needs to be transferred.
    a. If the 5east attending believes that the patient needs to be transferred, the attending is responsible for notifying the PICU attending.
- The PICU attending will need to accept the admission before the patient can be transferred.
- PICU residents need to write transfer orders and transfer note
    a. Residents may use the transfer tab on EPIC



From PICU to 5East:

If a patient becomes stable and no longer requires ICU level care, they will be transferred to 5East.

- PICU team will determine if a patient meets transfer criteria.
- PICU attending notifies the 5East attending to give signout.
- PICU resident contacts the 5East resident to give sign out.
    a. Need to sign out before a patient can be transferred!
- PICU residents write progress notes on the day of transfer. PICU residents are also responsible for placing transfer orders to 5East.
- BONUS: If the patient is being transferred to a non-hospitalist team (endocrine, trauma/surgery), then the accepting attending needs to be notified.
    a. Pediatric residents take care of endocrine patients, but the attending is the endocrinologist on call.
    b. Surgery residents take care of surgery/trauma patients, and the attending is the surgeon on call.

There will be occasions when patients need to be transferred to another hospital for escalation of care. In these situations, you will need to have a discussion with the attending to determine when it is appropriate. The attending will need to contact the outside hospital to determine if transfer is acceptable. The transfer protocol is different for each hospital, but below we have listed general steps for most hospital transfers.

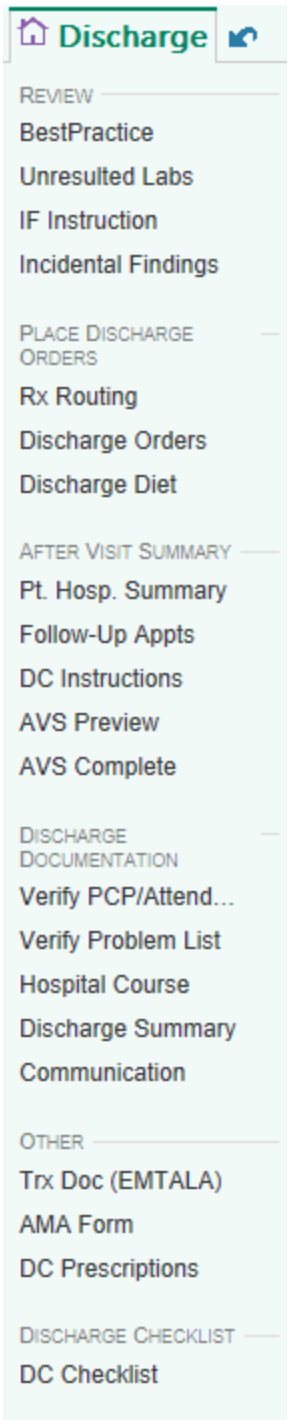
From UMass PICU to Outside Hospital:

- Attendings will need to speak with outside hospital to make sure the transfer is appropriate
- Once approved, you will need to determine if the patient can transfer via LifeFlight (Air or Ground). It will also need to be decided if the transfer team will be from UMass or the outside hospital.
- Patient will need to be 'Discharged'. Please go through the discharge tab on EPIC.
- Residents need to finish the Hospital Course and Discharge Summary before transfer. This will be printed and given to the transfer team.
- Residents will often need to perform sign-out to the accepting hospital. The accepting hospital will need to be called by the PICU and sign-out given to the residents and/or fellows taking over care.
- DON'T FORGET: This is a team decision. When in doubt, ask for help regarding what needs to be done for the transfer process!

Discharges

Direct discharges from the PICU can occur. Discharges are similar to discharges from the regular pediatric floor. Some patients may be more complicated (may require home services, equipment, etc), so be sure to go through discharges thoroughly with the team.

- Once a patient is deemed stable to be discharged home, make sure you review any needs that they will require as an outpatient
    - Home equipment (oxygen, BiPAP/CPAP, wheelchair)
    - Nursing services (VNA)
    - Please reach out to case management for assistance
- Send any medications to the preferred pharmacy
- Make sure all follow up appointments are set in place
- Please call the patient's PCP to update them on their PICU course and sign out any follow up that is required
- Go through the Discharge Tab on EPIC
    - Discharge Orders
    - Follow Up Appointments
    - Pt Hospital Summary
    - DC Instructions
    - AVS Complete
    - Verify Problem List
- For Notes:
    - Hospital Course and DC Summary does NOT need to be completed prior to discharge
    - Hospital Courses should be updated during the hospital course for patients to make it easy for residents
        - Please update Hospital courses every week in case a patient is discharged on a weekend when there is a cross-cover resident. This is much appreciated by all residents!



Clinical Resources

The Clinical Resources tab on EPIC has a ton of useful links for residents. There are also many resources available through the library and Woo Curriculum.

Some of the resident favorite tabs include:

1. On-Call Schedules → On Call Schedule (Med Ctr)
    a. This will bring you directly to the on call schedules for residents/attendings of all specialities
2. Clinical Applications
    a. LifeImage
        i. This is useful for patients who had imaging performed at outside hospitals. This is also useful when you are transferring patients to other hospitals. You should call radiology and have them upload images to LifeImage for the transfer.
    b. PIIC IX Web Single View (University)
        i. Username: clinicaluser PW: clinical user
        ii. This enables you to view telemetry for patients in the hospital from any computer. Very useful when you want to review telemetry on rounds.
3. Clinical References
    a. This tab has all the great educational resources for residents. Super useful but often underutilized!
    b. UpToDate
    c. CDC Immunization Schedule
    d. Lexicomp/Micromedex/Neofax
    e. VisualDx
4. Other Resources
    a. Antibiogram/ID
        i. Remember to look at this chart when determining which antibiotic to use. It uses data about antibacterial resistance in our community.

Sedation

During your time in the PICU, you will encounter patients who require sedation. There are a lot of different sedation medications that we use in pediatrics and each medication has its own benefits/risks. Sometimes we need sedation for quick procedures, but other times we will need long term sedation for critically ill patients who are mechanically intubated. In this section, our goal is to review different scales that we commonly use in the PICU and to review different medications and their side effects. We will also discuss different paralytic medications which are used in the PICU.

Goals of sedation:

- Sedation → putting your patient to sleep, decreases activity
- Amnesia → removing the memory
- Analgesia → removing the pain

Pediatric Glasgow Coma Scale

- Assess the level of consciousness of younger children, modified from GCS
- Lowest score (3) and Highest score (15)
- Severe injury associated with scores 8 or less
    - Consider alternative secure airway at this point

Eyes		**Verbal**		**Motor**	
Opens Spontaneously	4	Smiles, Interacts	5	Obey Commands, Moves Spontaneously	6
Opens to Voice	3	Cries but Consolable	4	Withdraws from Touch	5
Opens to Pain	2	Moans, Sometimes Inconsolable	3	Withdraws from Pain	4
No Response	1	Agitated	2	Abnormal Flexion (Decorticate)	3
		No Response	1	Abnormal Extension (Decerebrate)	2
				No Response	1

SBS Scoring (State Behavioral Scale) → describes sedation/agitation levels in pediatric intubated patients on mechanical ventilation

Score	Description	Comments
-3	Unresponsive	No spontaneous respiratory effort, No cough No response to noxious stimuli Does not move
-2	Responsive to noxious stimuli	Spontaneous yet supported breathing Coughs with suctioning, Responds to noxious stimuli Does not move/occasional movement of extremities
-1	Responsive to gentle touch/voice	Spontaneous but ineffective non-supported breaths Coughs with suctioning, Occasional movement Responds to touch/voice, Distresses with procedures
0	Awake, Able to calm	Spontaneous and effective breathing, Spontaneous cough Responds to voice/no external stimulus required Able to calm with comforting touch or voice
1	Restless, Difficult to calm	Spontaneous effective breathing/difficulty breathing with ventilator Responds to voice, Does not consistently calm Increased movement (restless, squirming)
2	Agitated	May have difficulty breathing with ventilator Unsafe (biting ETT, pulling lines, cannot be left alone) Increased movement (restless, thrashing, kicking legs)

Sedation Medications

Optimal agents for long term sedation for mechanically intubated patients can differ from agents used for short procedural sedation. There are also many combinations of agents that are used to achieve the sedation goal. This should be a discussion with the team to determine which agents are most appropriate. Below we will review the benefits and risks of different sedation agents commonly used in the PICU.

Opioids

- Analgesia
- Morphine
    - Pros: Standard opiate, many forms available
    - Cons: Histamine release (may exacerbate asthma, pruritus), Vasodilation and hypotension due to histamine release, Reduced bowel motility
- Fentanyl
    - Pros: Minimal cardiovascular instability, Fast on/Fast off
    - Cons: Chest wall rigidity, Respiratory depression, Pruritus

Benzodiazepines

- Sedative, Amnesia, Anxiolytic
- Need to use with an analgesic as there is NO pain control with benzodiazepines
- Midazolam (versed)
    - Pros: Fast on/Fast off
    - Cons: Respiratory depression, Mild hemodynamic instability (hypotension)

Ketamine

- Sedative, Analgesia, Amnesia - Produces a dissociative state
- NMDA Receptor Antagonist
- Pros
    - Stable hemodynamics, Great BP control (vasoconstrictor)
    - Can consider for asthmatics → bronchodilation
- Cons
    - Contraindicated for elevated ICP secondary to hypertension
    - Increases secretions and may cause laryngospasm
    - Emergence reaction, Dysphoria
    - Myoclonic jerks and nystagmus while sedated

Etomidate

- Sedative, Amnesia but NO Analgesia

- GABA Receptor Agonist
- Pros
    - Good BP control, stable hemodynamics
    - Can decrease ICP
- Cons
    - May have myoclonus activity
    - Adrenal suppression → Avoid in septic shock

Propofol

- Sedative, Amnesia
- GABA Receptor Agonist
- Pros
    - Fast on/Fast off - minimal post-sedation "grogginess"
    - Controls and decreases ICP
    - Anti-epileptic activity
- Cons
    - Hypotension due to vasodilation → bad for hemodynamic instability
    - Prolonged use at high doses may lead to PRIS (Propofol Related Infusion Syndrome)
        - Severe metabolic acidosis, often fatal)

Dexmedetomidine

- Sedative, Analgesia but NO Amnesia
- Alpha Agonist
- Pros
    - Lack of respiratory depression
    - May help facilitate withdrawal from opiates and benzodiazepines
- Cons
    - Bradycardia and hypotension

Barbituates

- Sedative but NO Amnesia/Analgesia
- Pentobarbital
    - Pros: Lowers ICP, Anticonvulsants
    - Cons: Hemodynamic instability, Immunosuppression (increased risk for hospital acquired infections)

Neuromuscular Blocking Agents/Paralytics

- Leads to paralysis but does NOT produce any analgesic or amnestic effects

    - Must have good pain and sedation control when using these agents
- You cannot use SBS scoring once a patient is on paralytics

- Non-Depolarizing Neuromuscular Blockade
    - Longer onset of action and duration than Depolarizing agents
    - More likely to develop fluid retention without muscle activity
    - Long term weakness/myopathy has been associated with continuous infusions and concomitant steroid use
    - Common agents:
        - Rocuronium, Vecuronium, Pancuronium
- Depolarizing Neuromuscular Blockade
    - Succinylcholine
        - Leads to hyperkalemia and muscle twitching
        - AVOID in neuromuscular disease, myopathies, crush injuries, malignant hyperthermia
        - May cause increased intraocular pressure (avoid in glaucoma/eye injury)
        - Vagotonic and may lead to arrhythmia - pretreatment with atropine

Endocrinology

DKA

Diabetic Ketoacidosis Definition:

1. pH <7.3 or HCO3 <15
2. Hyperglycemia > 200
3. Ketonemia (elevated betahydroxybutyrate) or Ketonuria

DKA can occur as the initial presentation of Type 1 DM in children/adolescents or can occur in known Type 1 diabetics for a variety of reasons (poor compliance, illness, failure of devices).

Severity of DKA:
Mild: pH 7.2-7.3
Moderate: pH 7.1-7.2
Severe: pH <7.1

Electrolyte Abnormalities:

- Elevated anion gap metabolic acidosis
- Sodium
    - Typically low sodium levels due to hyperglycemia and increased osmolality with fluid shifts
    - True Na = Measured Na + (1.6 x [glucose - 100] / 100)
- Potassium
    - Total body potassium depletion → urinary loss from osmotic diuresis, elevated aldosterone decreases potassium, vomiting
    - However, serum levels may initially appear normal or elevated due to redistribution of potassium
    - H+/K+ pump shifts K+ into the blood and H+ into cells to buffer the acidosis
    - Replacement with Kphos and KCl
        - Amount of replacement depends on potassium levels
- Phosphorus → low due to renal losses
- Magnesium → low due to renal losses
- Bicarbonate → low, metabolic acidosis

General Management:

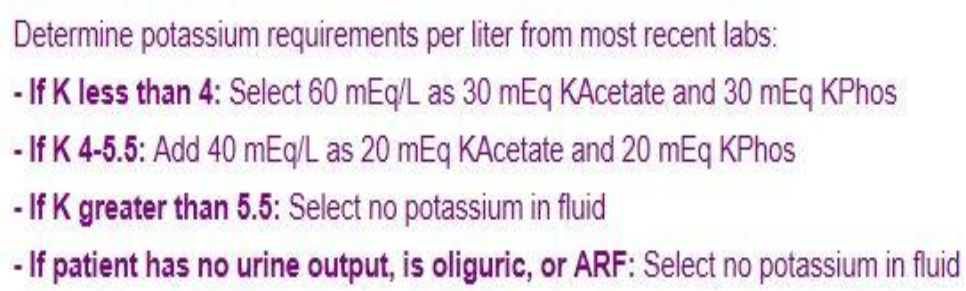
****Please refer to DKA Order Set in PICU for full details regarding orders/labs****

1. History and Symptoms
    a. History → polyuria, polydipsia, weight loss, vomiting, abdominal pain, fevers/recent illness
        i. If known T1DM, ask about insulin management
    b. Symptoms
        i. Ketone "fruity" smell, Kussmaul breathing, Lethargy and Mental status, Nausea, Vomiting, Abdominal pain
2. Fluids
    a. Patients need to be NPO while they are in DKA
    b. Initial fluid bolus of no more than 20ml/kg of NS
    c. Assess Dehydration
        i. Mild (<5%): Needs 1.5x MIVF
        ii. Moderate (5-7%): Needs 1.75x MIVF
        iii. Severe (>7%): Needs 2x MIVF

% Dehydration Parameters	Mild < 5%	Moderate 5-7%	Severe > 7%
Ph	7.2-7.3	7.1-7.2	< 7.1
Serum bicarbonate	< 15	< 12	< 5
Mental Status	Well, alert	Normal to fatigued, restless, irritable	Apathetic, lethargic, unconscious
Heart Rate	Normal	Normal to increased	Tachycardia, bradycardia in severe cases
Quality of Pulses	Normal	Normal to decreased	Weak, thready, impalpable
Breathing	Normal	Normal to fast	Deep
Mucous Membranes	Moist	Dry	Parched
Skin Turgor	Instant Recoil	Recoil in < 2 seconds	Recoil in > 2 seconds
Capillary Refill	Normal	Prolonged	Prolonged
Extremities	Warm	Cool	Cold, mottled, cyanotic

Table adapted from Waker PC. Diarrhea. In: Popovich NG, ed. Handbook of nonprescription drugs 15th ed. 2006 pp. 334.

    d. Two Bag System
        i. Bag 1 (NO dextrose)
        ii. Bag 2 (Dextrose
        iii. Rates are dependent on sugar and will change constantly
        iv. Need to determine how much potassium is included in fluids
    e. AVOID giving bicarbonate - leads to worse outcomes, only used in extreme scenarios and needs to be discussed with attending



2-BAG TITRATION PROTOCOL	Serum Glucose	NO Dextrose Bag (Bag 1)	Dextrose Bag (Bag 2)
Table (right) describes percent distribution of the TOTAL fluid infusion rate from each bag based on FSBS. Adjusting rates between bag 1 and 2 quickly and efficiently titrates glucose delivery. EXAMPLE: If TOTAL infusion rate is 120mLs/hr and FSBS is 307, then: BAG 1 = 0.75x120mL/hr = 90mLs/hr (75%) BAG 2 = 0.25x120mL/hr = 30mLs/hr (25%)	> 350	100%	0%
	301-350	75%	25%
	251-300	50%	50%
	201-250	25%	75%
	< 200	0%	100%
	FSBS < 70	**Stop insulin infusion**, call HO, recheck FSBS	

3. Insulin
    a. Continuous infusion of insulin started at 0.1 units/kg/hr
    b. Insulin should never be stopped if the patient is in DKA. Insulin is the ONLY treatment for acidosis
    c. You may decrease the insulin drip if the patient is becoming hypoglycemic or increase the amount of dextrose in fluids
    d. Goal will be to decrease glucose no greater than 100 per hour
    e. Goal glucose 200-250; glucose <200 increases risk of cerebral edema acutely
4. Labs
    a. Refer to DKA order set - in general, labs will be every 2 hours with blood glucose checks every 1 hour during initial phase
    b. Monitor glucose, electrolytes, VBG, urine, betahydroxybutyrate
    c. New onset suspected Type 1 DM labs must be sent with new diabetics
    d. Leukocytosis with left shift is common on initial labs due to stress response
5. Once DKA has resolved, patient with switch to subcutaneous insulin and stop IVF and insulin infusion
    a. Consult endocrinology to determine subcutaneous insulin plan
    b. Depending on attending, patients may stay on IVF until ketones are cleared from urine
    c. Once you give subcutaneous insulin, you will wait 30 min to 1 hr and then shut off insulin infusion

Complications:

- Cerebral Edema
    - Risk Factors: severe acidosis, substantially elevated BUN, severe hypocapnia, young child (<5 years) and/or new onset of diabetes
    - Minor criteria (moderately suspicious findings)

        Headache, vomiting, irritability, lethargy, not easily aroused from sleep, elevated blood pressure

- Major criteria (very suspicious findings)
    - Abnormal or deteriorating mental status, agitation, incontinence, bradycardia
- Diagnostic criteria (signs of significant brain injury, increased intracranial pressure, or brain herniation)
    - Abnormal response to pain, decorticate or decerebrate posture, abnormal pupillary response, abnormal neurogenic respiratory pattern

Treat suspected cerebral edema with mannitol, supportive measures, CT head, call neurosurgery ASAP

Treat for cerebral edema if:
1 diagnostic criterion
2 major criteria
1 major and 2 minor criteria
1 major and 1 minor criterion (if child <5 years)

Adrenal Insufficiency

Adrenal Insufficiency is caused by the impairment of the production and release of adrenocortical hormones. Adrenal glands release three main adrenocortical hormones:

1. Glucocorticoids (Cortisol)
2. Mineralocorticoids (Aldosterone)
3. Androgens

Adrenal Crisis occurs when there is an acute adrenal insufficiency

- Typically in the setting of stress, infection, injury
    - Ex: Sepsis, Adrenal gland hemorrhage, Thrombosis, Head trauma leading to pituitary failure, CAH
    - Don't forget about patients who are on chronic steroid therapy OR patients with panhypopituitarism and missed medications
- Adrenals are unable to release sufficient amount of cortisol

Symptoms of Acute Adrenal Crisis

- Symptoms are due to deficiency in mineralocorticoids and glucocorticoids
- GI symptoms (nausea, vomiting, abdominal pain)
- Electrolyte Abnormalities

    - Hyponatremia (+/- hyperkalemia)
    - Metabolic Acidosis
      Hypoglycemia
- Hypotension and Shock
    - Unresponsive to fluid resuscitation and inotropic medications

Diagnosis

- If acute adrenal crisis is suspected → draw baseline labs and start treatment ASAP with empiric steroids
    - Baseline Labs: Electrolytes, ACTH, Cortisol, Renin
- ACTH Stimulation Test
    - Measure baseline cortisol
    - Administer Cosyntropin
        - Infants: 15 mcg/kg, up to max dose 125 mcg
        - Children >2 years/Adolescents: 250 mcg
    - Check cortisol at 30 min and 60 min post Cosyntropin administration
    - If cortisol is low → AI confirmed

Treatment

- CONSULT ENDOCRINOLOGY - they may have specific dosing and treatment choices
- IV Fluid boluses may be given if hypotensive
    - Up to 60 ml/kg in 1st hour per shock guidelines
- Repletion of glucose by giving dextrose containing fluids
- Obtain EKG if hyperkalemic - hyperkalemia will resolve with appropriate steroid therapy, rarely will it require acute treatment to correct
- Stress Steroids
    - Hydrocortisone (Solu-Cortef) stress bolus: 50 - 100 mg/m2
    - Age Based dosing if body surface area not available
        - 0 - 3 years: 25 mg IV
        - 3 - 12 years: 50 mg IV
        - 12 years +: 100 mg IV
    - After initial bolus is given, patient will need to continue on maintenance dosing
        - Bolus dosing is divided into smaller doses over 24 hours
        - Ex: 100 mg IV bolus dosing, then give 25 mg IV every 6 hours

SIADH and DI

Antidiuretic Hormone (ADH)

- Released by hypothalamus in response to dehydration and increased plasma osmolality
- ADH increases free water reabsorption in kidneys

Syndrome of Inappropriate ADH (SIADH)

- Excessive ADH secretion leading to impairment in water excretion, water retention and hyponatremia
    - Hyponatremia due to 1) dilution from increased total body water and 2) increased urinary sodium excretion
- Diagnosis
    - Increased Urine Osm (> 100 mOsm/kg) and Urine Na (> 30mEq/L)
    - Decreased Serum Osm (< 280 mOsm/kg)
    - Patients are euvolemic (increased total body water, normal total body sodium)
- Causes
    - CNS disorders (stroke, head trauma, brain tumor, post surgical)
    - Ectopic tumor production (SCC of lung)
    - Drugs (cyclophosphamide, oxcarbazepine, SSRIs)
    - Pulmonary Disease (pneumonia, acute respiratory failure)
- Treatment
    - Treat underlying disease process
    - Fluid restriction
    - Sodium replacement if symptomatic and poor response to fluid restriction
- Cerebral Salt Wasting
    - Can be confused with SIADH
    - Mechanism poorly understood → Occurs with a neurological injury that leads to excessive salt wasting from kidneys
        - Subarachnoid hemorrhage is a common insult that leads to CSW
        - Theories include increase in natriuretic peptide (BNP) after cerebral injury will decrease Na reabsorption in kidney and leads to increased urine Na and urine output
    - Difference between SIADH and CSW = volume status (hypovolemic in CSW vs euvolemic in SIADH)
    - Treatment → sodium repletion, hypertonic saline can be used especially in patient with intracranial hemorrhage

Diabetes Insipidus (DI)

- Decreased secretion of ADH (central/neurogenic) or Resistance to ADH (nephrogenic)
    - Leads to polyuria, polydipsia, dehydration, hypernatremia
- Diagnosis
    - Decreased Urine Osm (< 300 mOsm/kg) and Urine Na (< 20 mmol/L)
    - Increased Serum Osm (> 300 mOsm/kg)
    - Hypernatremia (> 145 mmol/L)
- Causes
    - Central DI: Head trauma/surgery, Brain tumor, infiltrative disorders - essentially any injury to pituitary gland
    - Nephrogenic DI: Genetic disorders of kidney, Lithium toxicity, Hypercalcemia
- Treatment
    - Central DI: Desmopressin (DDAVP)
    - Nephrogenic DI: Low sodium diet, HCTZ, NSAIDs

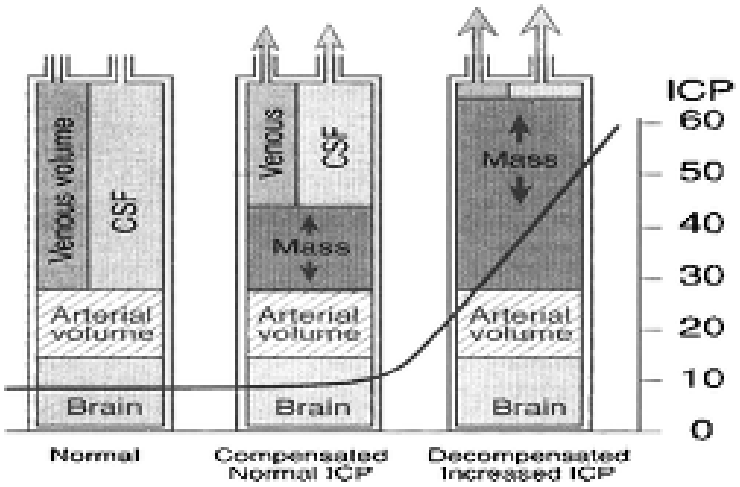
	Mechanism	**Volume Status**	**Serum Na & Serum Osm**	**Urine Na & Urine Osm**	**Urine Output**
SIADH	Excess ADH	Euvolemia	Low	High	Low
DI	Inadequate ADH	Hypovolemia	High	Low	High
CSW	Excess sodium wasting	Hypovolemia	Low	High	High

Neurology

TBI

The skull has a fixed volume that is made up of 3 components: Brain, Blood, CSF. An increase in any one of the components (or an unaccounted mass lesion) can affect the volume and pressure inside the head.

- Example: Brain swelling after TBI increases the amount of brain in the skull. The other components will try to compensate (decrease in venous blood and CSF) until it cannot compensate any further. Once compensation can go no further, it leads to risk of herniation.
- This is referred to as the Monro-Kellie Doctrine



Cerebral Perfusion Pressure (CPP)

CPP = MAP - ICP

MAP (mean systemic arterial pressure), ICP (Intracranial pressure)

- Can replace ICP with CVP (central venous pressure) when CVP is higher
- Low cerebral perfusion pressures are associated with ischemia, secondary brain injuries and worse clinical outcomes
- TBI can result in increased vasospasms leading to increased cerebral vascular resistance and decreased CPP → results in ischemia
- Optimize CPP by maintaining MAP and decreasing ICP
    - May need vasopressors to maintain MAP
    - Phenylephrine or epinephrine are preferred choices
- CPP Thresholds: aim to keep CPP above the thresholds for better outcomes
    - Adults/Adolescents 60 mmHg
    - Children 50 mmHg
    - Infants 40 mmHg

Cushing's Triad

- Hypertension, Bradycardia, Irregular Respirations
- Can indicate impending herniation with increased ICP in addition to pupillary changes (asymmetric pupils, fixed/dilated pupils) and posturing

Management of Increased ICP

- Definition of Increased ICP → ICP > 20 mmHg
    - Normal ICP = 5 - 10 mmHg
- Monitoring ICP
    - Place monitor if GCS <8
    - There are different types of ICP monitors
        - EVD (external ventricular device) → can also be used to drain CSF
        - Subdural, intraparenchymal, epidural

- Treatment Guidelines
    - HOB elevated to 30^0
        - Allows for adequate venous drainage
    - Avoid Hypotension
        - Hypotension leads to decreased MAP and ischemia
        - On the other hand, hypertension can lead to increase cerebral blood flow and worsening cerebral edema
    - Normothermia
        - Hyperthermia → increased cerebral metabolism → increased oxygen consumption and increased cerebral blood flow (worsening edema)
        - Every 1^0C above normothermia = 7% increase in brain metabolism
    - Euglycemia
        - Goal Glucose <180
        - Hyper- and Hypoglycemia leads to increased tissue acidosis from anaerobic metabolism, free radical generation, and osmolar changes → poor clinical outcomes
    - Sodium levels
        - Aim for normal to elevated levels of Na (140 - 155)
        - Hyponatremia → cerebral edema due to osmolar gradient
    - Normal ventilation
        - Goal PaCO2 35-40
        - Hyperventilation may cause some decreased ICP initially (decreased PaCO2 → cerebral vasoconstriction) but can lead to ischemia especially in first day or two after TBI

    - Hyperosmolar therapy
        - Goal Osm 290 - 320
        - Fluid shifts from low concentration to high concentration
        - Hypertonic Saline (3% to 23.4%)
            - 3ml/kg of 3% NS
            - Intermittent boluses of 23.4% NS (0.5 ml/kg up to 30ml)
            - Ideally given via central access due to risk of injury with peripheral extravasation
        - Mannitol
            - 1 g/kg boluses every 4-6 hours
    - Sedation
        - Sedation can help decrease CNS metabolic demand
        - Fentanyl or morphine PLUS midazolam
        - Neuromuscular blockade → may decrease ICP elevations associated with coughing and dyssynchrony with vents
    - Seizure Prophylaxis
        - Preferred medication: Levetiracetam
        - Time course recommendations vary between patients
- Refractory ICP
    - CSF Drainage
        - EVD placement allows for ICP monitoring and CSF drainage
    - Pentobarbital
        - Loading dose (~5 mg/kg) followed by continuous (1-4 mg/kg/hr)
        - Decrease cerebral metabolic demand → decrease cerebral blood flow and ICP
        - Place on cEEG and titrate dose to produce burst-suppression pattern
        - May delay brain death exam and can cause hypotension
    - Surgery → decompressive craniectomy
    - Hypothermia
        - May reduce cerebral metabolism
        - However, no high quality evidence and should only be used in the worst cases

Status Epilepticus

Definition: Seizure activity lasting longer than 5 minutes or clusters of seizure activity without return to baseline mental status in between.

- Previous definitions used 30 minutes as time length
- Refractory Status Epilepticus → seizures that continue despite the use of benzodiazepines and one anti-epileptic drug

Common Etiologies

- Non compliance with AEDs, CNS infection, metabolic (hypoglycemia, electrolyte abnormalities), stroke, increased ICP, ingestion, trauma, vasculitis, hypertensive crisis, sepsis, PRES (posterior reversible encephalopathy syndrome), ADEM (acute disseminated encephalomyelitis)

Treatment Algorithm

Seizure Onset

Support ABCs, Oxygen, Monitor
Establish IV access
POC glucose, Labs

If IV access → Lorazepam 0.1mg/kg
If no IV access → Rectal Diazepam 0.2 - 0.5 mg/kg (rounded up to closest dose)

- If 2-5 years old, give 0.5 mg/kg
- If 6-11 years, give 0.3 mg/kg
- If 12+ years, give 0.2 mg/kg

If seizure persists...repeat lorazepam or diazepam dose as above
Consider AED

- Levetiracetam 20 mg/kg loading dose

Call Pediatric Neurology and ICU attending

Repeat Levetiracetam 20mg/kg
Add Fosphenytoin 20 mg/kg

Add Phenobarbital 20 mg/kg over 15- 20 minutes

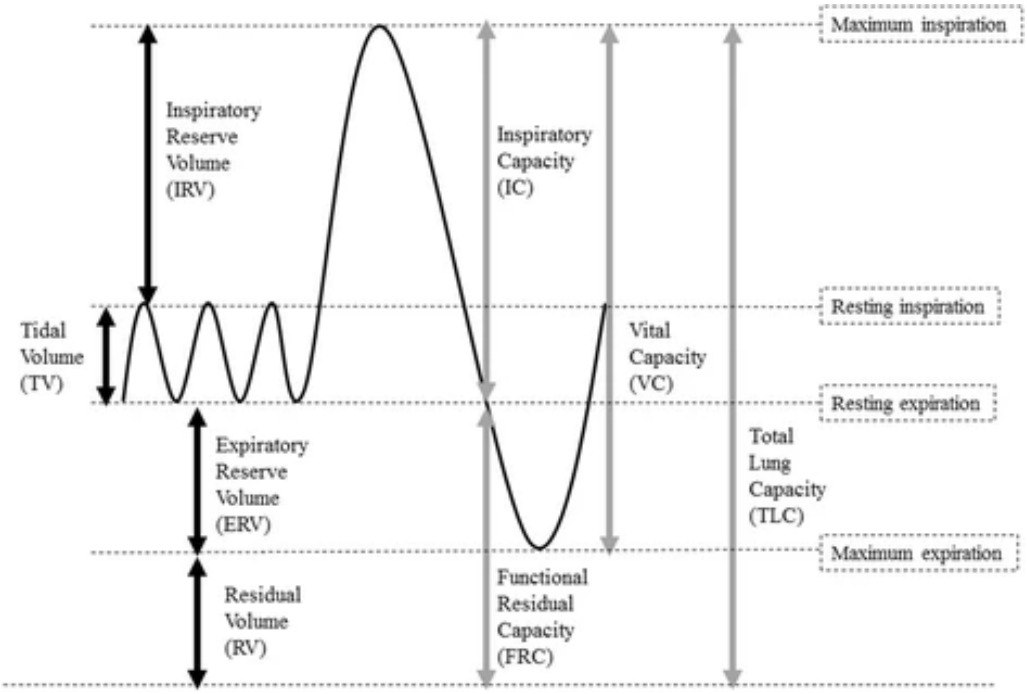
If persistent seizures despite benzodiazepines and up to three AEDs, will need to consider pharmacological coma

- Rapid sequence intubation
- Midazolam
- Pentobarbital
- Propofol

Labs to Consider:
CBC
CMP
Rapid electrolytes (iStat Chem 8)
Ca, Mg, Phos
Tox screen
AED level
Urine, blood, CSF cultures
Head CT
EEG
Metabolic screen (pyruvate, lactate, ammonia, urine)
Obtain Newborn Screen

Respiratory

Basic Respiratory Terms



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Tidal Volume	Volume of air exchanged during a normal respiration
Inspiratory Reserve Volume	Max amount of air that can be forcibly inspired after tidal inspiration
Expiratory Reserve Volume	Max amount of air that can be forcibly expired after tidal expiration
Residual Volume	Volume of air that remains in lungs after forced expiration
Inspiratory Capacity	Total amount of air that can be inspired (TV + IRV)
Functional Residual Capacity	Total amount of air that remains in lungs after a tidal expiration (RV + ERV)
Vital Capacity	Total amount of exchangeable air (TV + IRV + ERV)
Total Lung Capacity	Total amount of exchangeable and non-exchangeable air

Hypoxemia

A-a gradient

- Difference between alveolar and arterial oxygen (PAO2 - PaO2)
- High gradient → lots of O2 in alveolar, little O2 in arteries
- Low/Normal gradient → little O2 in alveolar and little O2 in arteries

PAO2 (Alveolar oxygen)

- PAO2 = (P_{Bar} - P_{H2O}) x FiO2 - (PaCO2/RQ)
    - RQ = 0.8, P_{Bar} = 760, P_{H2O} = 47
- PAO2 = (713 x FiO2) - (PaCO2/0.8)

Mechanisms for Hypoxemia

1. Hypoventilation
    a. Normal A-a gradient
    b. Patient is not moving enough air → abnormal inhalation and expiration leading to less O2 in alveoli to diffuse across to capillaries
    c. Ex. Overdose with decreased RR, Sedation, Neuromuscular Disorders, Obesity
2. VQ Mismatch
    a. High A-a gradient
    b. Imbalance of blood flow and ventilation
    c. Ex. Asthma, Pulmonary Embolism, COPD, Pneumonia
3. Right to Left Shunt
    a. High A-a gradient
    b. When blood passes from right side of heart to left side of heart without becoming oxygenated
    c. Anatomical shunt → alveoli are bypassed
        i. Pulmonary AVMs, intracardiac shunts (ASD, VSD, etc)
    d. Physiological shunt → non ventilated alveoli are perfused
        i. Atelectasis, alveolar filling disease (pneumonia, ARDS)
    e. Supplemental oxygen does NOT help
4. Impaired Diffusion
    a. High A-a gradient
    b. Impairment of oxygen diffusion from alveoli to capillaries
    c. Ex. Interstitial inflammation and fibrosis in lung disease, emphysema
5. Low Inspired PO2
    a. Normal A-a gradient
    b. Inspired oxygen content is low → seen with high altitude climbers

Oxygen Delivery

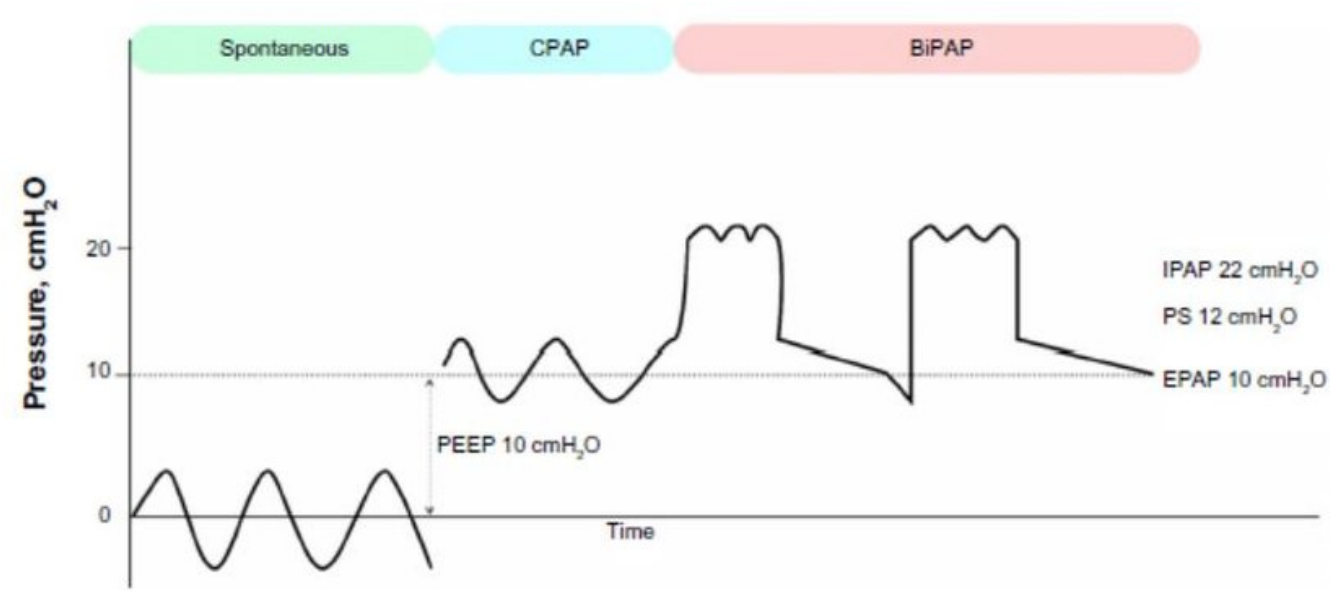
Type of O_2 Delivery	Flow Rates	FiO_2	How to Titrate	Notes
Low-flow nasal cannula	1–6 L/min	Each L/min adds ~4% FiO_2 above room air[a] 1 L/min = 20% 2 L/min = 24% 3 L/min = 28% 4 L/min = 32% 5 L/min = 36% 6 L/min = 40%	Titrate flow rate only	Best for patients with normal respiratory rates and tidal volumes
Simple face mask	~6–12 L/min	35–60%[a]	Titrate flow rate only	Minimum of 6 L/min flow is required to prevent re-breathing CO_2
Venturi mask	Fixed flow based on adapter chosen	Adapters are usually available in 24%, 28%, 31%, 35%, 40%	Titrate FiO_2 only	Adapter entrains a set amount of ambient air to deliver a fixed FiO_2
Non-rebreather mask	10–15 L/min	100%	Nontitratable	Short term bridge therapy only
High-flow nasal cannula	Up to 60 L/min	30–100%	Titrate flow rate and FiO_2	Administers PEEP with high flow rate

[a]Varies based on respiratory rate and minute ventilation

Non-Invasive Ventilation

Non-Invasive Ventilation (NIV) is useful for patients with respiratory distress prior to mechanical invasive ventilation.

1. HFNC (high flow nasal cannula)
    a. Humidified air at higher flow volumes
    b. Cannula size does set limits on how much flow can be delivered
2. CPAP (continuous positive airway pressure)
    a. Continuous pressure during inspiration and expiration
    b. Patient breathes spontaneously, but breaths are not supported
3. BiPAP (biphasic positive airway pressure)
    a. Continuous flow of air that increases/decreases
    b. Set IPAP (inspiratory) and EPAP (expiratory)
        i. IPAP = PIP
        ii. EPAP = PEEP
    c. Can be patient triggered (delivers IPAP each time patient breathes on their own) or set rate (delivers IPAP at set intervals, typically used if patient is hypoventilating)



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Intubation

Indications for Intubation

- Inability to protect airway (neuromuscular disease, seizures, CNS injury)
- Airway compromise (croup, foreign body, ingestion, allergic reaction, trauma)
- Sedation or procedure requiring airway protection
- Failure to ventilate and/or oxygenate (respiratory failure)
- Minimize oxygen consumption and metabolic demands (sepsis, arrest)

Equipment - SO STABLE

- Suction - ensure that it is hooked up to the suction and working properly
- Oxygen
- Stylet, stethoscope - stylet for the ETT if needed and stethoscope to listen to the lungs afterwards
- Tube (ETT)
- Airway - alternative airways should be available (LMA - laryngeal mask airway), measure the size from tragus to lips
- Bag and Mask
- Laryngoscope
- ETCO2

Endotracheal Tube

- Endotracheal Size
    - Formula can be used for children 2-10 years of age
    - Uncuffed ETT = (age in year/4) + 4
    - Cuffed ETT = (age in years/4) + 3.5
- Endotracheal Depth
    - Depth = ETT diameter x3

Laryngoscope

- Mac (Curved) and Miller (Straight) blades
- Miller blade more commonly used in younger children due omega shaped epiglottis and straight blade will lift up epiglottis
- Mac blade is positioned within vallecula and more common in older children

Age	**Blade Type/Size**
Neonates	Miller 0-1
<2 years	Miller 1, Mac 1
2 - 8 years	Miller 2, Mac 2
8 - 12 years	Miller 2-3, Mac 2-3
>12 years	Miller 3, Mac 3

Intubation Medications

- Premedication
    - Atropine 0.02 mg/kg → useful in young infants <1 yr, prevents bradycardia secondary to vagal stimulation
    - Lidocaine 1 mg/kg → consider in patients with elevated ICP
- Sedation
    - Fentanyl (1-2 mcg/kg slow push) - minimal hemodynamic compromise, but can cause rigid chest syndrome
    - Midazolam (0.1-0.3 mg/kg) - may cause slight hypotension
    - Etomidate (0.3 mg/kg) - no effect on hemodynamics, may cause adrenal suppression
    - Ketamine (1-2 mg/kg) - increased HR/BP, bronchodilation, hypersalivation and laryngospasm, emergence reaction, possibility of increased ICP
    - Propofol (1-2 mg/kg) - neuroprotective, may cause hypotension

- Paralytic
    - Rocuronium (0.6 - 1.2 mg/kg)
    - Vecuronium (0.1 - 0.2 mg/kg)
    - Succinylcholine (1-2 mg/kg) - avoid in hyperkalemia, malignant hyperthermia, increased ICP, burns, crush injury, neuromuscular disease
- Specific Patient Scenarios
    - General PICU patient - typically does well with fentanyl, midazolam and rocuronium
    - Hypotensive - ketamine or etomidate
    - Increased ICP - etomidate, avoid succinylcholine and ketamine due to concern for augmentation of increased ICP
    - Septic shock - ketamine, but AVOID etomidate due to adrenal suppression
    - Asthma - ketamine, however try to avoid intubation due to difficulty ventilating patients, air trapping, barotrauma

Mechanical Ventilation

	Term	**Definition**	**General Vent Setting**
PIP	Peak Inspiratory Pressure	Total pressure delivered used to overcome airway resistance and lung compliance (PEEP + IP)	As needed to deliver goal tidal volume. Typically from Teens to 20s
PEEP	Positive End Expiratory Pressure	Pressure at end of expiration	Start at 5 cc H2O, can increase as needed to increase oxygenation. ARDS uses PEEP 7-9.
IP	Inspiratory Pressure	Difference between PIP - PEEP	As needed to deliver goal tidal volume
Vt (TV)	Tidal Volume	Volume of air entering lungs during inspiration	5-7 ml/kg, use lower 4-6 ml/kg if poor compliance
It	Inspiratory Time	Time spent in inspiration	~0.5 sec infants, 1 sec children/teens
I:E	Inspiratory to Expiratory Ratio	Expiration generally takes longer than inspiration.	Ratio typically around 1:2, can be prolonged with obstructive lung disease

PS	Pressure Support	Amount of pressure given to support spontaneous breaths	Ranges from 0 to IP value
MAP	Mean Airway Pressure	Average pressure in the airway over time (both inspiration and expiration)	Dependent on PEEP, It, PIP
FiO2	Fraction of Inhaled Oxygen	Room air (21%), try to maintain <60% to avoid oxygen toxicity	21% - 100%
RR	Respiratory Rate	Amount of respirations in one minute, adjusted for age	10-30 breaths/min

Oxygenation

- Process of diffusing oxygen from alveoli to pulmonary capillaries
- Determined by MAP and FiO2
    - MAP can be affected by inspiratory time, PEEP, PIP
    - PEEP tends to be the most effective at increasing MAP and thus improving oxygenation

Ventilation

- Process of inhalation and exhalation, delivering oxygen to the alveoli and exhaling CO2
- Determined by RR and TV
    - Minute Ventilation = RR x TV
- Ex. To decrease the CO2 levels, you would increase the RR or increase the TV

Compliance = ΔV (change in volume) / ΔP (change in pressure)

- Higher compliance = easier to inflate lungs

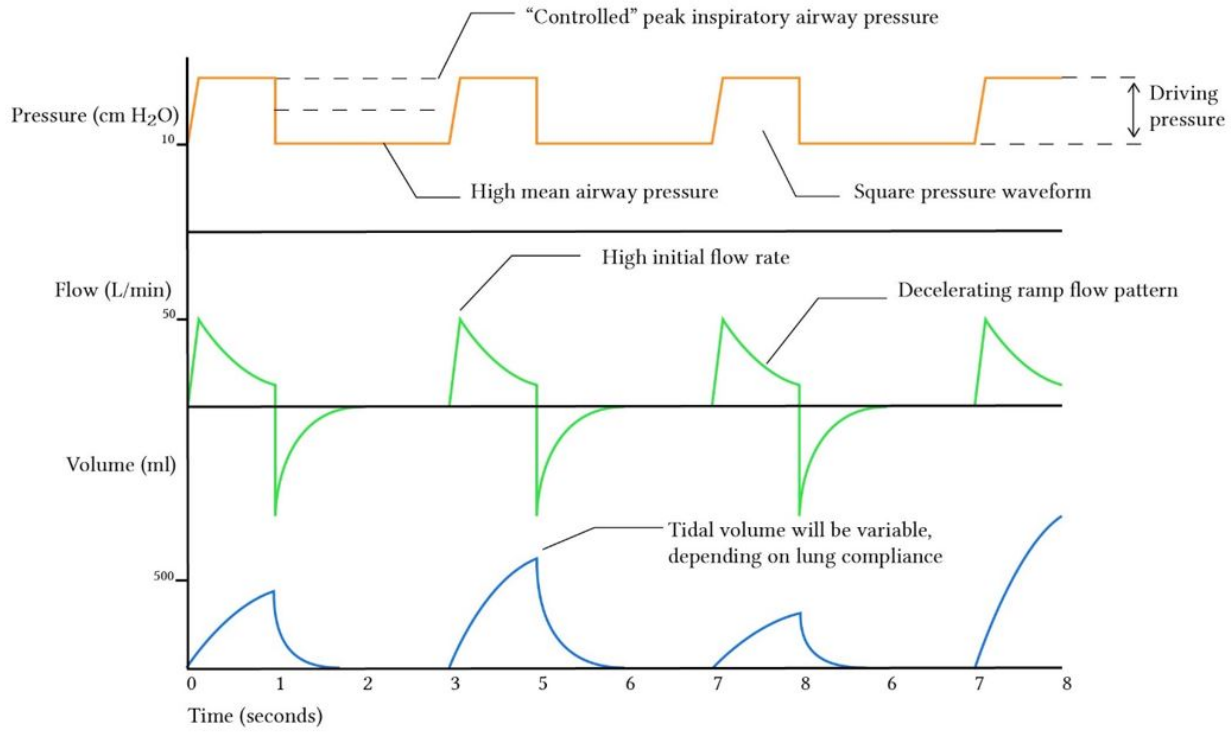
Modes of Conventional Ventilation

1. When does the ventilator breath for the patient?
    a. Assist Control (AC)
        i. Delivers full pressure with every breath both spontaneous, patient triggered AND mandatory
        ii. Uncommonly used in the PICU
    b. Synchronized Intermittent Mandatory Ventilation (SIMV)
        i. Delivers full pressure/volume with a set number of mandatory breaths determined by provider

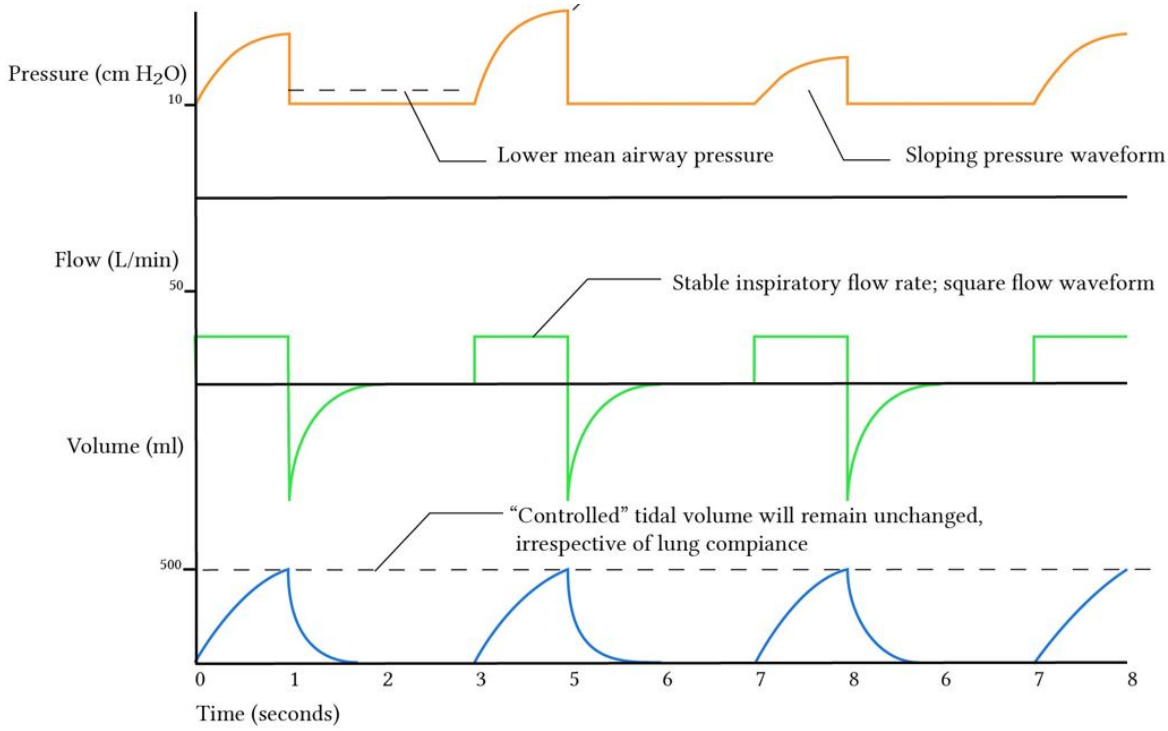
ii. If spontaneous patient triggered breaths occur close to mandatory set rate, those breaths will get full pressure/volume - BUT the machine will not go above the set rate
iii. Any spontaneous patient triggered breaths above the set rate are only supported with pressure support

2. How does the ventilator deliver the breath?
    a. Pressure Control (PC)
        i. Delivers a set pressure, deceleration flow
        ii. Set PIP/IP, PEEP with variable Tidal Volumes
        iii. Pros - more comfortable with deceleration, protective against barotrauma, preferred for non-compliant lungs, increased duration of alveolar recruitment, better for air leak
        iv. Cons - tidal volume is highly dependent on compliance, volumes may vary significantly, sudden increase in compliance may lead to high volumes (volutrauma)
    b. Volume Control (VC)
        i. Delivers a set volume, constant flow
        ii. Set Tidal Volume, PEEP with variable IP/PIP
        iii. Pros - minute ventilation is guaranteed, better with ‘healthy’ lungs (intubated for status epilepticus, TBI), less pressure needed for more compliant lungs
        iv. Cons - less effective with air leaks, higher pressures with less compliance can lead to barotrauma
    c. Pressure Regulated Volume Control (PRVC)
        i. Set a goal tidal volume while the ventilator monitors pressure/volume it has delivered in previous breaths - ventilator will then deliver certain pressure to obtain goal tidal volume
        ii. Uses deceleration flow AND guarantees minute ventilation, can adjust to dynamic compliance changes
    d. Pressure Support (PS)
        i. Set PEEP and IP/PIP, No mandatory rate is set
        ii. Ventilator delivers pressures only with spontaneous patient triggered breaths
        iii. Useful for extubation readiness trials

Pressure Control Ventilation



Volume Control Ventilation



Extubation Readiness

Patient's should be continuously assessed for extubation readiness. Assessment is performed via ERTs (extubation readiness trials).

Before you consider extubation, remember to ask the following questions:

1. Is your patient ready for extubation?
    - Why were they intubated in the first place?
    - Are they awake?
    - Are they able to protect their own airway?
    - Is their respiratory drive intact?
    - Are there significant secretions?
    - Any upcoming procedures that require sedation/intubation?
    - Is their cardiac function acceptable?
        - Removing positive pressure will increase LV afterload

Optimization prior to extubation

- Decrease sedation infusions to minimize respiratory depression and increase alertness
- Check for air leak
    - May require Lasix or Steroids to decrease airway edema
- Metabolic alkalosis
    - Patients may have metabolic alkalosis secondary to diuretics or CO2 retention
    - There is some benefit in acetazolamide administration prior to extubation to create a favorable acid-base balance

Extubation Readiness Trial

- Changing patient to Pressure Support and monitoring their response
- Settings
    - PEEP 5
    - Pressure Support based on tube size - the pressure is used to overcome the resistance of breathing through a tube. Smaller the tube = higher the pressure support
        - ETT <3.5 = PS 10
        - ETT 3.5 - 4 = PS 8
        - ETT >4 = PS 10
- Monitor patient's respiratory rate, work of breathing, tidal volumes, apnea, oxygen saturation
    - Attempt to perform ERT for at least 1 hour to determine patient's response in preparation for extubation

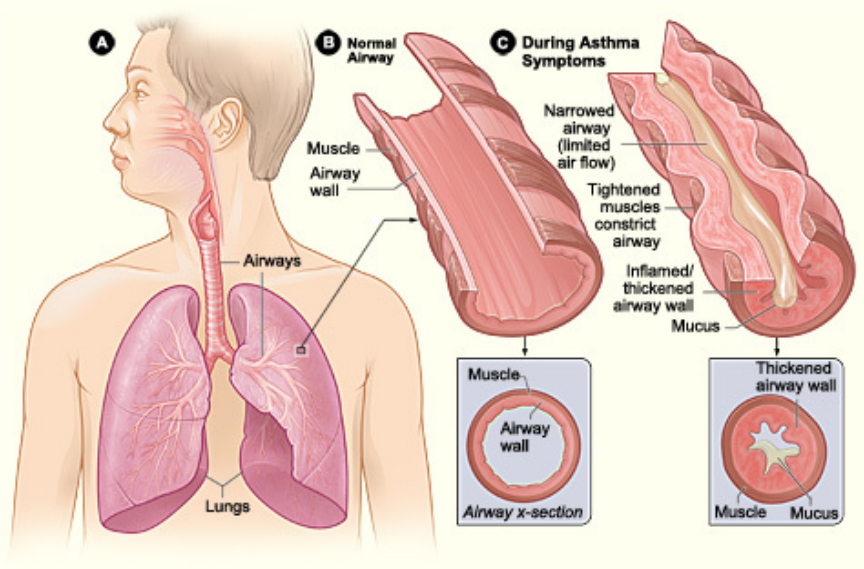
Extubation

- MMSOAP
    - **Monitor** - place patient on monitor
    - **Meds** - have medications ready for re-intubation OR medications like racemic epinephrine/albuterol for post extubation reactivity or swelling
    - **Suction** - make sure suction equipment is readily available and to suction the patient prior to extubation
    - **Oxygen** - preoxygenate prior to extubate
    - **Airway** - airway equipment should be ready to re-intubation or equipment ready for CPAP/BiPAP/NC after extubation
    - **Personnel** - have respiratory therapy, nurses, attending at bedside and make sure you know the number for anesthesia in case you need to re-intubate

Status Asthmaticus

Asthma Pathophysiology

- Airway inflammation, Excessive mucus production, mucus plugging, airway bronchospasm



Presentation

- Respiratory Distress (retractions, cannot speak in full sentences), Cyanosis, Rapid Shallow Breathing
- Inspiratory and Expiratory Wheezing
    - No wheezing heard is BAD sign → lack of air movement in lungs

- Hypoxemia
    - Albuterol may cause transient hypoxemia due to pulmonary vasodilation and shunting
- Blood gas may show hypocapnea and respiratory alkalosis (fast breathing)
    - If normal to elevated CO2 while tachypneic → BAD SIGN, may indicate fatigue and impending respiratory failure
- Lactic Acidosis → can be due to 1) increased work of respiratory muscles and 2) side effect of albuterol treatment
- Air trapping leads to increased intra-thoracic pressure
    - During severe exacerbations, increased pressure can impair venous return and decrease cardiac output

Treatment

- Oxygen as needed to correct hypoxemia
    - Aim for goal oxygen >90%
- Albuterol
    - Beta-2-Agonist → relaxes bronchial smooth muscles leading to bronchodilation
    - Should be part of the initial "stacked duonebs"
        - Three doses of 2.5mg - 5mg of albuterol in combination with ipratropium
    - Continuous medication administration if patient does not respond to stacked nebulizer treatments or intermittent treatments
        - Continuous dose 0.5mg/kg/hr (max 20mg/hr)
    - Monitor for hypokalemia, tachycardia, hyperglycemia
    - Levalbuterol is considered in some cases of persistent tachycardia as there is research that shows less cardiovascular side effects
- Ipratropium Bromide (Atrovent)
    - Anticholinergic → adds additional bronchodilation, commonly used in combination with albuterol
    - Should be part of the initial "stacked duonebs"
        - Three doses of 0.25mg - 0.5mg of ipratropium in combination with albuterol
    - After initial treatment, you may administer intermittent doses every 4-6 hours
- Steroids (Methylprednisolone)
    - Reduces inflammation; Methylprednisolone is used in more severe exacerbations
    - Prednisone and dexamethasone are oral medications, used in less severe cases
    - Methylprednisolone
        - Loading dose of 2mg/kg followed by 0.5 - 1mg/kg every 6 hours
        - Doses up to 60mg to 80mg every 6 hours have been used in older patients with severe exacerbations and then weaned with improvement

- Magnesium
    - Smooth muscle relaxation
    - Should be given with a bolus of fluids as Magnesium can lead to hypotension
    - Doses of 50mg/kg up to max dose 2g
- Theophylline/Aminophylline
    - Phosphodiesterase inhibitor → increases levels of cAMP and leads to bronchodilation
    - Loading dose 6mg/kg followed by maintenance infusion 0.5-1mg/kg/hr
    - Narrow therapeutic window, goal levels between 10-15 mcg/ml
        - Must check serum levels every 6-12 hours
    - Toxic effects from elevated levels - vomiting, tachycardia, seizures
- Terbutaline
    - Intravenous beta agonist leading to bronchodilation
    - Useful when inhaled beta agonist are not effective due to poor airflow
    - Loading dose 2-10mcg/kg followed by maintenance infusion 0.1-0.4 mcg/kg/min (max 6mcg/kg/min)
        - Titrate maintenance by 0.1-1 mcg/kg/min until desired effect
    - May lead to increased myocardial demand from tachycardia → demand ischemia, arrhythmias
        - Monitor troponin and EKGs, CK
    - Also associated with hypotension, hyperglycemia, hypokalemia
        - Monitor BMPs, vitals
- Epinephrine
    - Can act as a bronchodilator and pulmonary vasodilator
    - Doses 0.01mg/kg (max 0.5mg) every 20 minutes for up to 3 doses
    - Must use the 1mg/mL concentration, administer subQ vs IM
- Heliox
    - Mixture of Helium and Oxygen
    - Promotes laminar flow instead of turbulent flow → less airway resistance to laminar flow → decreased work of breathing
- Non Invasive Ventilation
    - HFNC, BiPAP, CPAP
    - Helps avoid endotracheal intubation
    - Positive pressure can stent open collapsing/narrowed airways and allow for more complete exhalation to decrease the amount of air trapping
- Ketamine
    - Dissociative sedative agent that leads to bronchodilation
- AVOID endotracheal intubation if possible

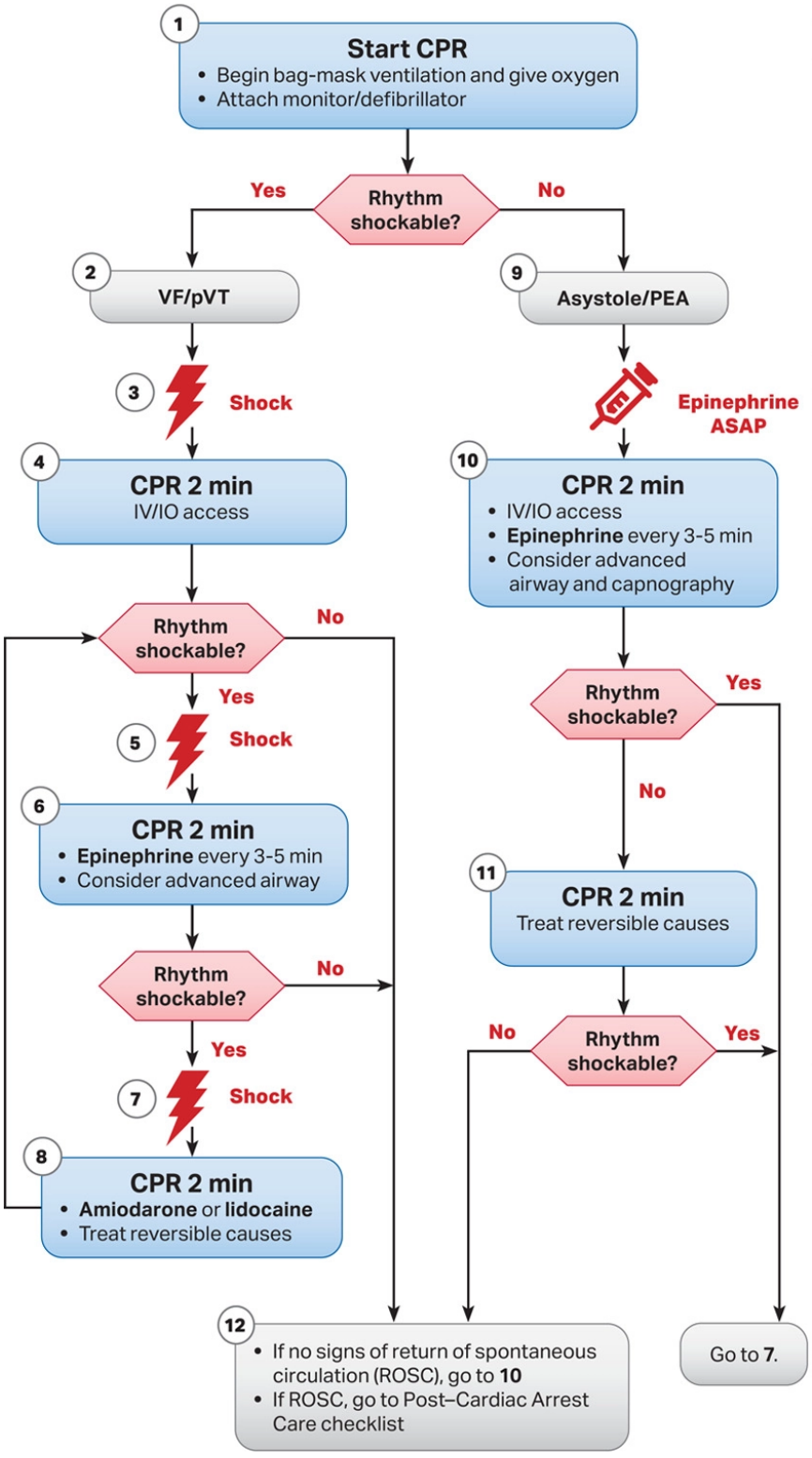
Intubation

- Indications for Intubation
  - Severely altered mental status, severe hypoxia not responsive to supplemental O2, increasing CO2, impending respiratory or cardiac arrest
- Intubation can worsen bronchospasms by irritating the airways, and high pressures may lead to pneumothorax
- Midazolam, Ketamine and Rocuronium are commonly used agents
- Prepare for circulatory depression and hypotension after intubation
- Ventilation
  - Aim for low RR, low PEEP, long expiratory time, permissive hypercapnea

Cardiology

PALS - Cardiac Arrest

Pediatric Cardiac Arrest Algorithm



CPR Quality

- Push hard (≥⅓ of anteroposterior diameter of chest) and fast (100-120/min) and allow complete chest recoil
- Minimize interruptions in compressions
- Change compressor every 2 minutes, or sooner if fatigued
- If no advanced airway, 15:2 compression-ventilation ratio
- If advanced airway, provide continuous compressions and give a breath every 2-3 seconds

Shock Energy for Defibrillation

- First shock 2 J/kg
- Second shock 4 J/kg
- Subsequent shocks ≥4 J/kg, maximum 10 J/kg or adult dose

Drug Therapy

- **Epinephrine IV/IO dose:** 0.01 mg/kg (0.1 mL/kg of the 0.1 mg/mL concentration). Max dose 1 mg. Repeat every 3-5 minutes. If no IV/IO access, may give endotracheal dose: 0.1 mg/kg (0.1 mL/kg of the 1 mg/mL concentration).
- **Amiodarone IV/IO dose:** 5 mg/kg bolus during cardiac arrest. May repeat up to 3 total doses for refractory VF/pulseless VT
  or
  Lidocaine IV/IO dose: Initial: 1 mg/kg loading dose

Advanced Airway

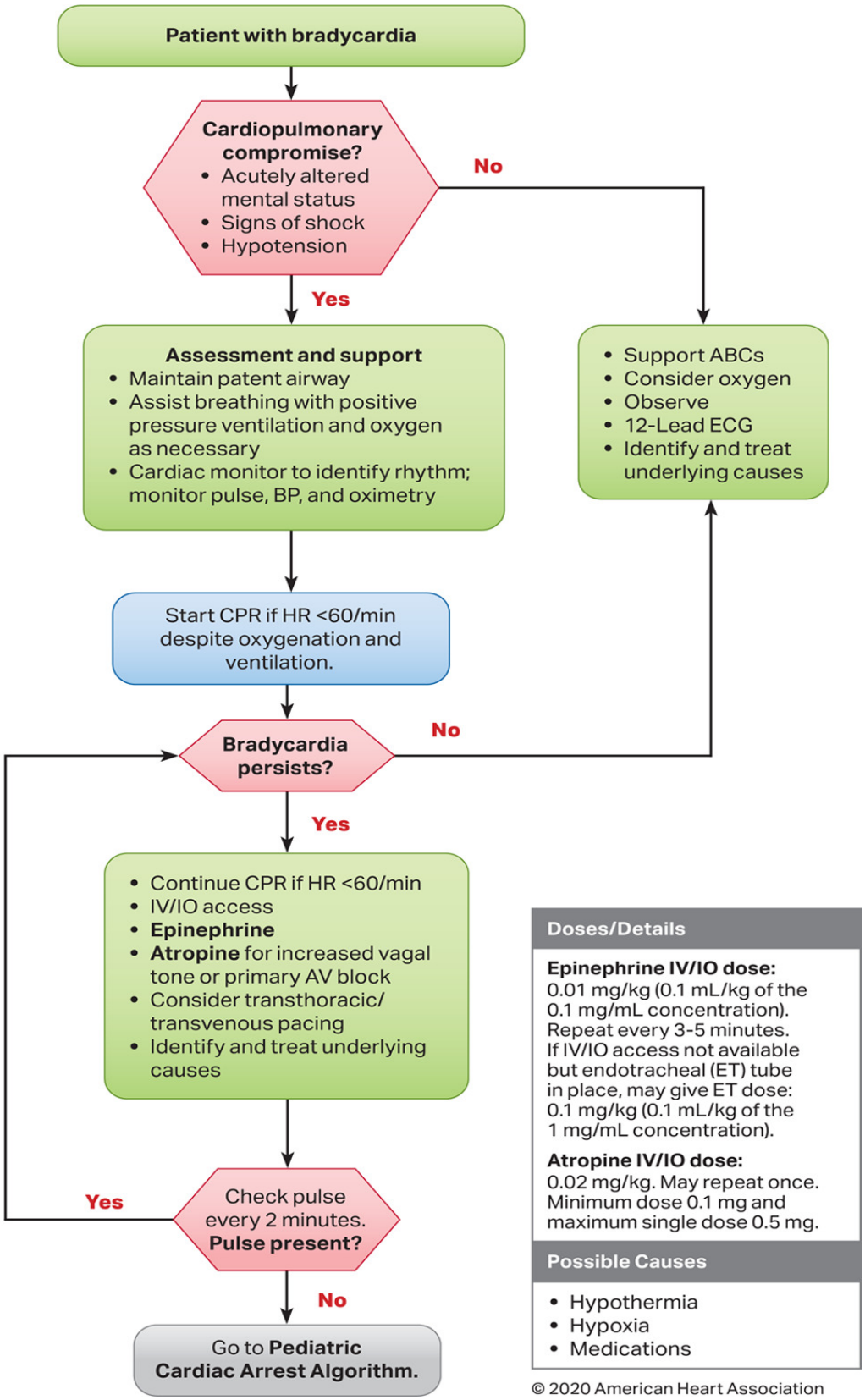
- Endotracheal intubation or supraglottic advanced airway
- Waveform capnography or capnometry to confirm and monitor ET tube placement

Reversible Causes

- **H**ypovolemia
- **H**ypoxia
- **H**ydrogen ion (acidosis)
- **H**ypoglycemia
- **H**ypo-/hyperkalemia
- **H**ypothermia
- **T**ension pneumothorax
- **T**amponade, cardiac
- **T**oxins
- **T**hrombosis, pulmonary
- **T**hrombosis, coronary

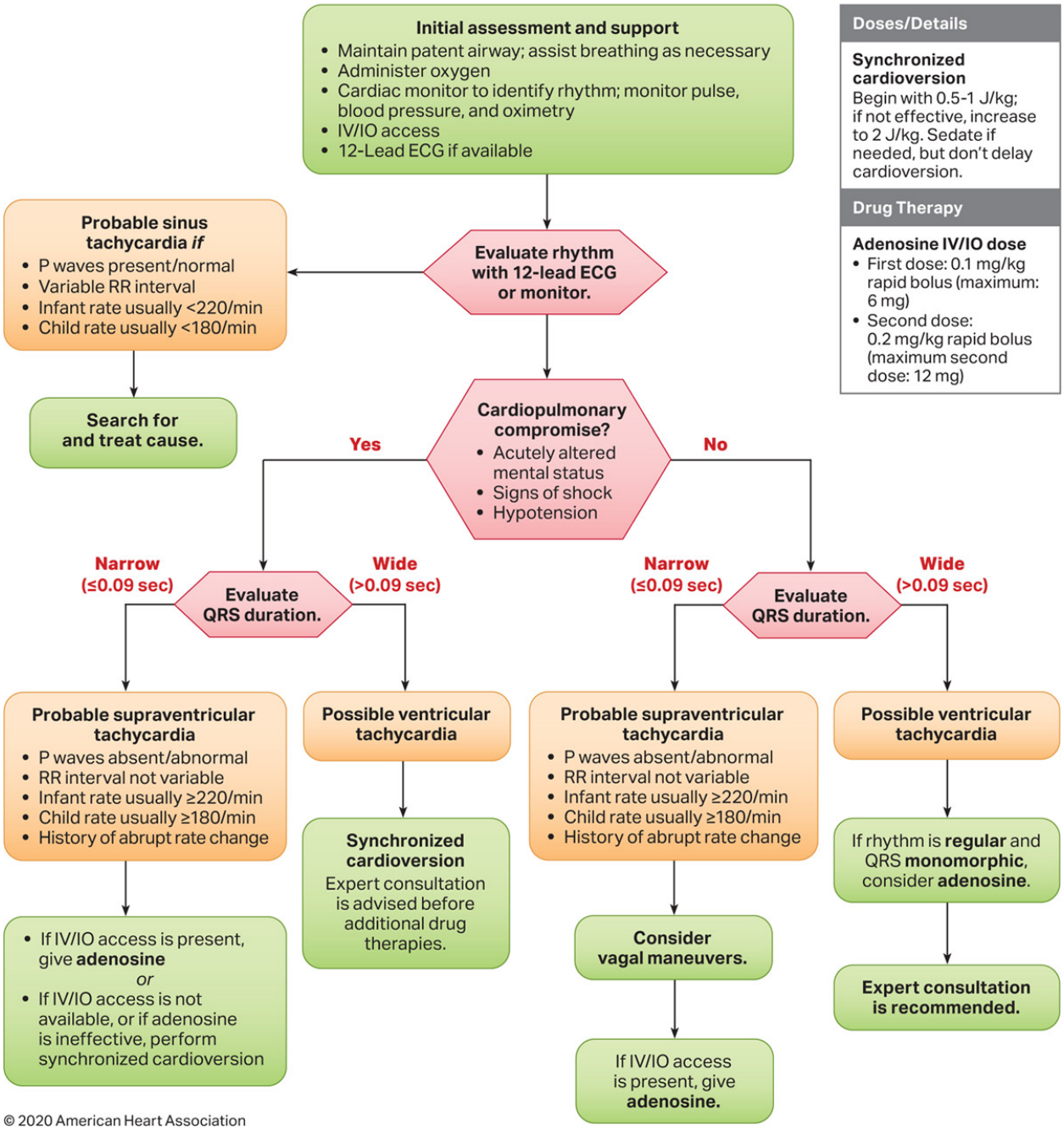
PALS - Bradycardia

Pediatric Bradycardia With a Pulse Algorithm



PALS - Tachycardia

Pediatric Tachycardia With a Pulse Algorithm



Shock

Cardiac Output (CO) = Heart Rate (HR) X Stroke Volume (SV)
Systemic Blood Pressure (BP) = CO X Systemic Vascular Resistance (SVR)

What is Shock?
State of circulatory dysfunction that leads to **inadequate tissue perfusion** with **impaired cellular metabolism**.

Inadequate tissue perfusion → anaerobic metabolism → accumulation of lactic acid (metabolic acidosis) → cell death, organ dysfunction, death

Compensated vs Uncompensated Shock

- Compensated: Blood pressure is maintained as normal, but there is still inadequate tissue perfusion. However, there is no overt organ dysfunction as metabolic needs are being met
    - Signs of compensated shock → agitation, fatigue, tachycardia, tachypnea, oliguria, ileus, glycogenolysis, prolonged cap refill
- Uncompensated: Body can no longer compensate and tissue perfusion decreases leading to end organ dysfunction. Typically have hypotension and lactic acidosis.
    - Sign of uncompensated shock → AMS, tachycardia (can lead to bradycardia), hypotensive, acute respiratory failure, acute renal failure, GI bleeding, shock liver, DIC, hypoglycemia

**Remember in children, blood pressure is able to be maintained for a long time until the very end. If the child is hypotensive, it is a late finding

Types of Shock:

1. Cardiogenic → disorder of cardiac function leading to decreased cardiac output
    a. "Pump failure"
    b. Congenital heart disease, myocarditis, cardiomyopathy, arrhythmia
2. Hypovolemic → inadequate intravascular volume leading to decreased preload/cardiac output
    a. "Loss of volume"
    b. Fluid loss (diarrhea, vomiting, renal losses), hemorrhage, burns, third-spacing
3. Obstructive → extra-cardiac causes of pump failure leading to reduced right ventricular output, maintains normal intravascular volume
    a. "Flow obstruction"
    b. Pulmonary embolism, pneumothorax, cardiac tamponade

4. Distributive → severe peripheral vasodilation due to loss of vascular tone or loss of vascular volume due to disordered permeability
    a. Septic, anaphylaxis, neurogenic

	Normal	Cardiogenic	Hypovolemic	Obstructive	Distributive
PCWP (preload)					
CI					
SVR (afterload)					
CVP					
SVO2					

PCWP - Pulmonary Capillary Wedge Pressure, CI - Cardiac Index, SVR - Systemic Vascular Resistance, CVP - Central Venous Pressure, SVO2 - mixed venous oxygen saturation

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