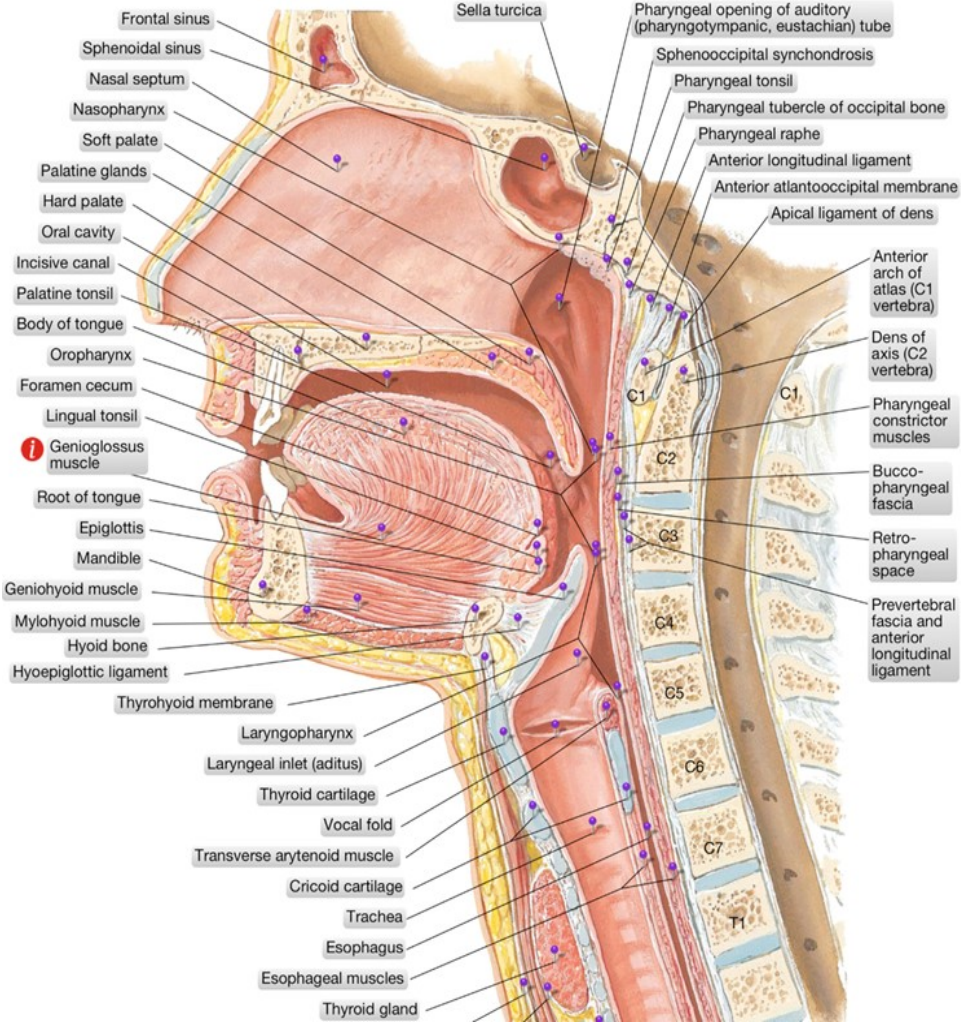
PICU

AIRWAY


Frontal sinus
Sphenoidal sinus
Nasal septum
Nasopharynx
Soft palate
Palatine glands
Hard palate
Oral cavity
Incisive canal
Palatine tonsil
Body of tongue
Oropharynx
Foramen cecum
Lingual tonsil
Genioglossus muscle
Root of tongue
Epiglottis
Mandible
Geniohyoid muscle
Mylohyoid muscle
Hyoid bone
Hyoepiglottic ligament
Thyrohyoid membrane
Laryngopharynx
Laryngeal inlet (aditus)
Thyroid cartilage
Vocal fold
Transverse arytenoid muscle
Cricoid cartilage
Trachea
Esophagus
Esophageal muscles
Thyroid gland
Sella turcica
Pharyngeal opening of auditory (pharyngotympanic, eustachian) tube
Sphenooccipital synchondrosis
Pharyngeal tonsil
Pharyngeal tubercle of occipital bone
Pharyngeal raphe
Anterior longitudinal ligament
Anterior atlantooccipital membrane
Apical ligament of dens
Anterior arch of atlas (C1 vertebra)
Dens of axis (C2 vertebra)
C1
C1
Pharyngeal constrictor muscles
C2
Bucco-pharyngeal fascia
C3
Retro-pharyngeal space
C4
Prevertebral fascia and anterior longitudinal ligament
C5
C6
C7
T1

INTUBATION SEQUENCES

Pre-intubation: 100% FiO_2 for > 3 min, PPIV, suction, $ETCO_2$ sensor, oral airway, alternative ETT and blades. Have NS bolus available if patient has ↓ BP with PPV

RAPID SEQUENCE INTUBATION

Etomidate IV/IO**: 0.3 mg/kg (max 20 mg) OR Propofol** IV/IO**: 2 mg/kg (max 100 mg)**
Rocuronium IV/IO**: 1 mg/kg (max 100mg) OR Succinylcholine** IV/IO**: 1 mg/kg (max 150mg)**
(Succinylcholine may be given IM at 3-5 mg/kg, max 150mg, infants may require higher IV doses)
Consider: ***Atropine*** *IV:* ***0.02 mg/kg*** *(min 0.1mg, max 1mg) for < 5yrs or with succinylcholine*
Hold cricoid pressure from loss of consciousness until ETT confirmed
After Intubation**: Midazolam** IV/IO/IM/IN**: 0.2 mg/kg (max 10 mg)**

STANDARD SEQUENCE

Fentanyl IV/IO**: 2 mcg/kg (may increase if BP stable)**
Midazolam IV/IO/IM/IN**: 0.2 mg/kg (less for low BP, max 10 mg)**
Consider: ***Atropine*** *IV:* ***0.02 mg/kg*** *(min 0.1mg, max 1mg) for children < 5yrs*
Vecuronium IV/IO**: 0.1 mg/kg OR Rocuronium** IV/IO**: 1 mg/kg (max 100 mg)**

ASTHMA SEQUENCE

Consider: ***Atropine*** *IV:* ***0.02 mg/kg*** *(min 0.1mg, max 1mg) for children < 5yrs*
Ketamine IV/IO**: 2 mg/kg** (max 5 mg/kg) IM: **7 mg/kg** (max 13 mg/kg)
Vecuronium IV/IO**: 0.1 mg/kg**
After Intubation**: Midazolam** IV/IO/IM/IN**: 0.2 mg/kg (max 10 mg)**

HEMODYNAMIC INSTABILITY SEQUENCE

Ketamine IV/IO**: 2 mg/kg,** IM**: 7 mg/kg OR Etomidate** IV/IO**: 0.3 mg/kg (max 20 mg)**
Consider: ***Atropine*** *IV:* ***0.02 mg/kg*** *(min 0.1mg, max 1mg) for children < 5yrs*
Vecuronium IV/IO**: 0.1 mg/kg OR Rocuronium** IV/IO**: 1 mg/kg (max 100 mg)**
After Intubation: **Midazolam** IV/IO/IM/IN**: 0.1 mg/kg (max 8mg if BPs are normal)**

HEAD INJURY SEQUENCE

Lidocaine IV/IO**: 1mg/kg (max 100 mg)**
Etomidate IV/IO**: 0.3 mg/kg (max 20 mg)**
Consider: Atropine *IV:* ***0.02 mg/kg (min 0.1mg, max 1mg) for children < 5yrs***
Rocuronium IV/IO**: 1 mg/kg (max 100 mg) OR Vecuronium** IV/IO**: 0.1 mg/kg IV**

RENAL OR LIVER FAILURE CONSIDERATIONS

Propofol IV/IO: **1-2 mg/kg (↓ ICP, BP) OR Etomidate** IV/IO: **0.3 mg/kg**
Consider: ***Midazolam*** *IV/IO/IM/IN:* ***0.1 mg/kg*** **(max 5 mg)**
Atracurium IV/IO: **0.4 mg/kg OR Cisatracurium** IV/IO**: 0.2 mg/kg**
(Both rapidly degraded by plasma esterases, may need an infusion)

ACID BASE CORRECTIONS

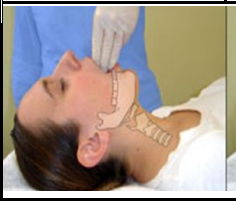
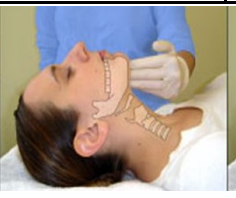
Metabolic Acidosis (starts in 30 min, done by 12 hrs)	**$PaCO_2$ = [(1.5)(HCO_3) + 8] ± 2 OR $PaCO_2$ = (HCO_3) + 15** **$PaCO_2$ = Decimal digits of pH**
Metabolic Alkalosis	**↑ $PaCO_2$ by 0.7 mmHg per 1 $^{mEq}/_{L}$ ↑ in [HCO_3]**
Respiratory Acidosis (Comp complete in 3 days)	**↑ [HCO_3] by 1 $^{mEq}/_{L}$ per ↑in 10 mmHg $PaCO_2$** **↑ [HCO_3] by 4 $^{mEq}/_{L}$ per ↑in 10 mmHg $PaCO_2$** (after 3 days)
Respiratory Alkalosis	**↓ [HCO_3] by 2 $^{mEq}/_{L}$ per ↓ in 10 mmHg $PaCO_2$** **↓ [HCO_3] by 5 $^{mEq}/_{L}$ per ↓ in 10 mmHg $PaCO_2$**

Rapid Airway Exam

Not really predictive , but good practice
↑ Risk: <1y/o, underweight, ASA III/IV

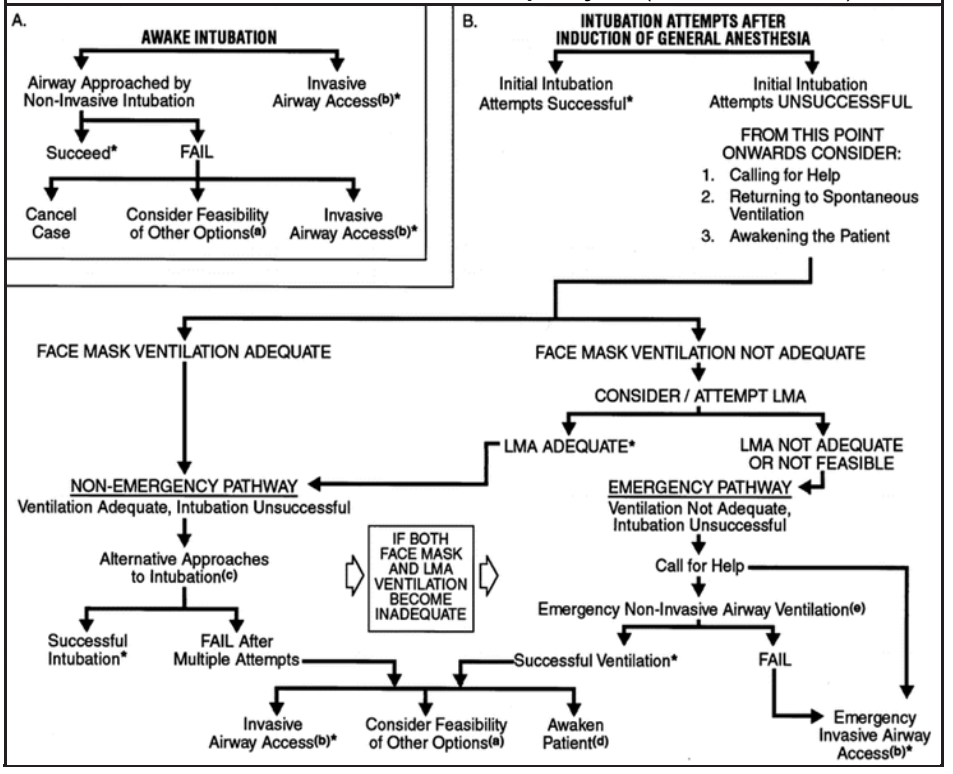
L	**L**ook externally: Malformations, ability to BMV
E	**E**valuate 3-3-2
M	**M**allampati score
O	Airway **O**bstruction?
N	**N**eck mobility
S	**S**aturations

3-3-2 Rule

Mouth Opening	Tip of mentum to hyoid bone	Thyromental distance
		
Access to airway and ability to obtain glottic view	Ability to deflect tongue with the laryngoscope	Predicts location of larynx to base of the tongue (“anterior view”)

DIFFICULT AIRWAY

Provide maximal amount of oxygen at each step, Call for help (**TART**), adjuvants
Consider risks of awake v. sedated v. paralyzed (**ABILITY TO BMV**)



Airway Equipment Sizes

Suction catheter for ETT size	
Size	**Min ETT**
6 F	**2.5**
8 F	**3.5**
10 F	**4.0**
14 F	**5.0**

Nasal Airways			
Size	**L (mm)**	**ID (mm)**	**OD (mm)**
20	100	3.6	6.7
22	105	4.6	7.3
24	110	5.2	8
26	118	5.8	8.7
28	125	6.0	9.3
30	127	6.6	10
32	140	7.2	10.7
34	155	7.8	11.3
36	170	9.0	12

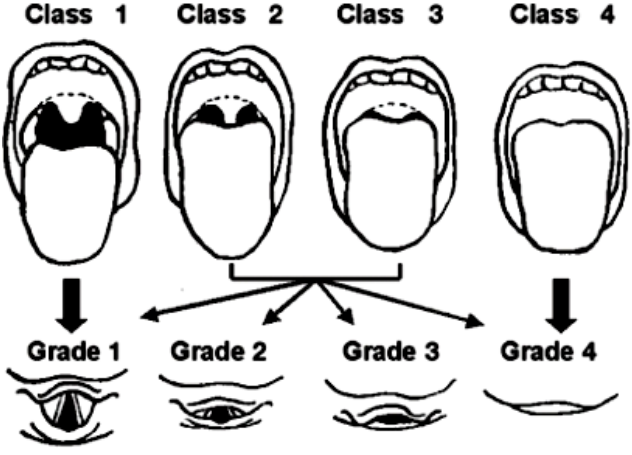
Oral Airways	
Size	**mm**
00	40
0	50
1	60
2	70
3	80
4	90
5	100
6	110

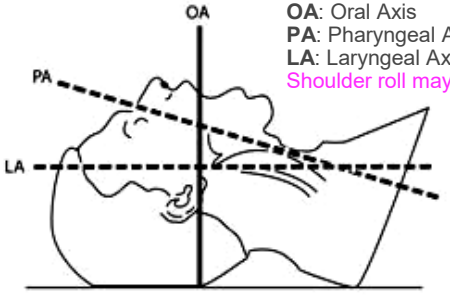
Glidescope Blades	
GVL #	**Wt**
0	< 1.5 kg
1	1.5 – 3.6 kg
2	1.8 – 10 kg
2.5	10 – 28 kg
3	10 kg – adult
4	> 50 kg

LMA Sizes	
LMA #	**Wt**
1	< 5 kg
1.5	5 – 10 kg
2	10 – 20 kg
2.5	20 – 30 kg
3	30 – 50 kg
4	50 – 70 kg
5	70 – 100 kg

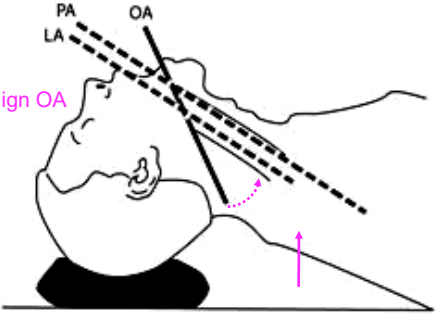
Diameter (mm) = French/3

Mallampati Classification & Cormack-Lehane View Grade





OA: Oral Axis
PA: Pharyngeal Axis
LA: Laryngeal Axis
Shoulder roll may help align OA



ANAPHYLAXIS

100% O_2, ABCs, Consider Nebulized albuterol or nebulized epinephrine
EPINEPHRINE: SubQ/IM (1:1,000) 0.01 mL/kg (max 0.5 mL) repeat q10min
IV/IO (1:10,000) 0.01 mL/kg, then 0.1 mcg/kg/min
EpiPen: 0.1 mg: 7.5-13 kg, 0.15 mg: 13-25 kg, 0.3 mg: >25 kg
Hypotension: Trendelenburg position, 20 mL/kg NS, **Epinephrine** infusion
Antihistamine: **Benadryl** 1-2 mg/kg IM/IV over 5 min OR **Atarax** 0.5-1 mg/kg
Corticosteroids**: Solumedrol** IV/**Prednisone** PO 2 mg/kg (late reaction)
Glucagon: 0.02 mg/kg (max 1 mg) load and 0.05-0.1 mCg/kg/hr (max 5 mg/hr)

UPPER AIRWAY OBSTRUCTION

Nebulized Epinephrine 2.25%: 0.5 mL q2hrs (use 0.5 mL/kg 1:1000 in 3 mL NS)
Dexamethasone: 0.25-0.5 mg/kg/dose q 6 hr; For extubation 0.25-0.5 mg/kg/dose
Heliox: 70/30 or 60/40 (cannot use if FiO_2 requirement is >35%)
Consider **Neo-synephrine** 0.25%, 2 drops q4hr x3 days, nasal trumpet, cool mist

ASTHMA

Albuterol: 0.1-0.3 mg/kg (max 5 mg) neb q20 min for 2 hours OR 0.5 mg/kg/hr to 40 mg/hr
Ipratropium: <12y/o: 0.25 mg, >12y/o 0.5 mg q20 min for 2hrs for 3 doses
Solumedrol/Prednisone: 2 mg/kg IV load then 1 mg/kg/dose IV q6hrs
***OR* Decadron:** 0.6 mg/kg IV load (max 16 mg) then 0.2 mg/kg/dose q6-12hrs
$MgSO_4$: 50 mg/kg IV over 20-30 min, max 2 grams, ***CI*: 25-50 $^{mg}/_{kg/hr}$ (goal >4)**
Terbutaline IV:10 mcg/kg over 10 min, 0.1-10 mcg/kg/min (max 6 mcg/kg/min)
Ketamine: 1-2 mg/kg IV bolus then 0.5-1 mg/kg/hr, **Sevofluourane or ECMO**

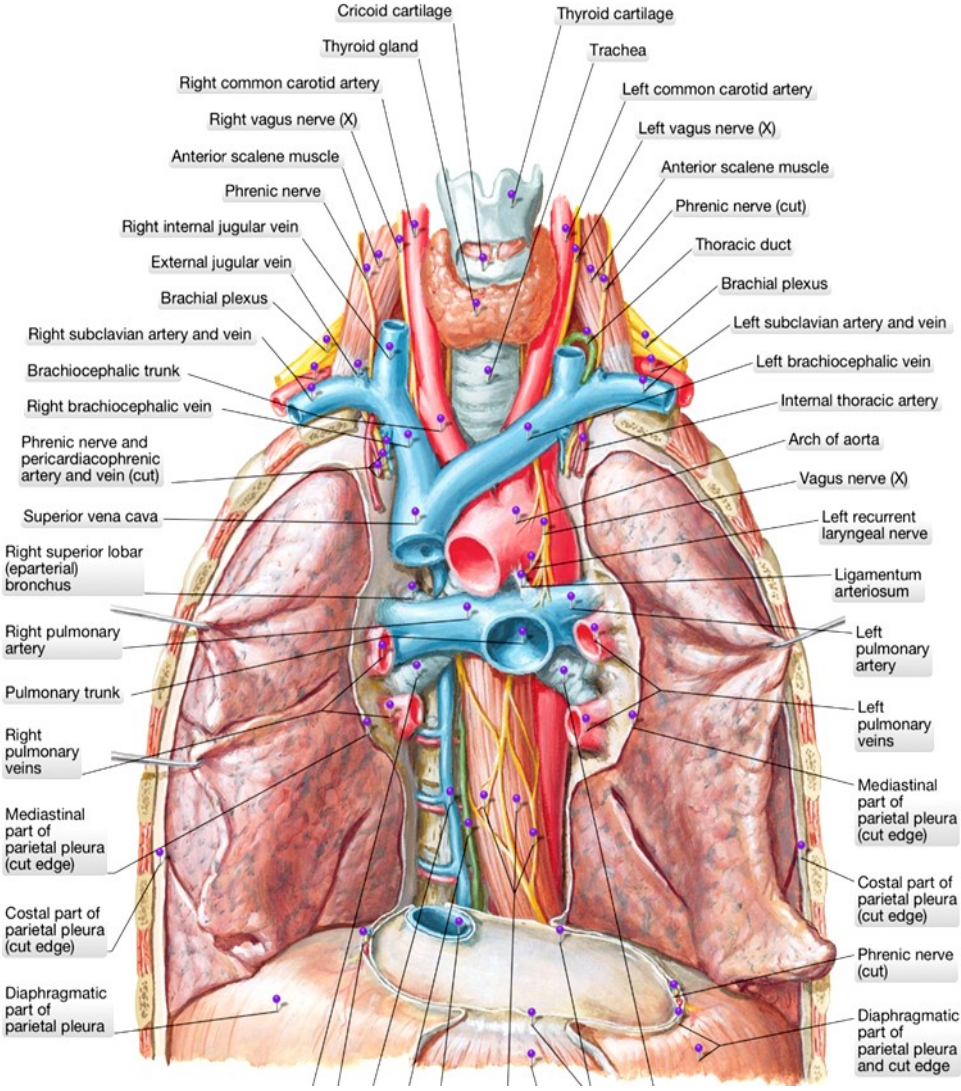
STEROID POTENCY / CONVERSION

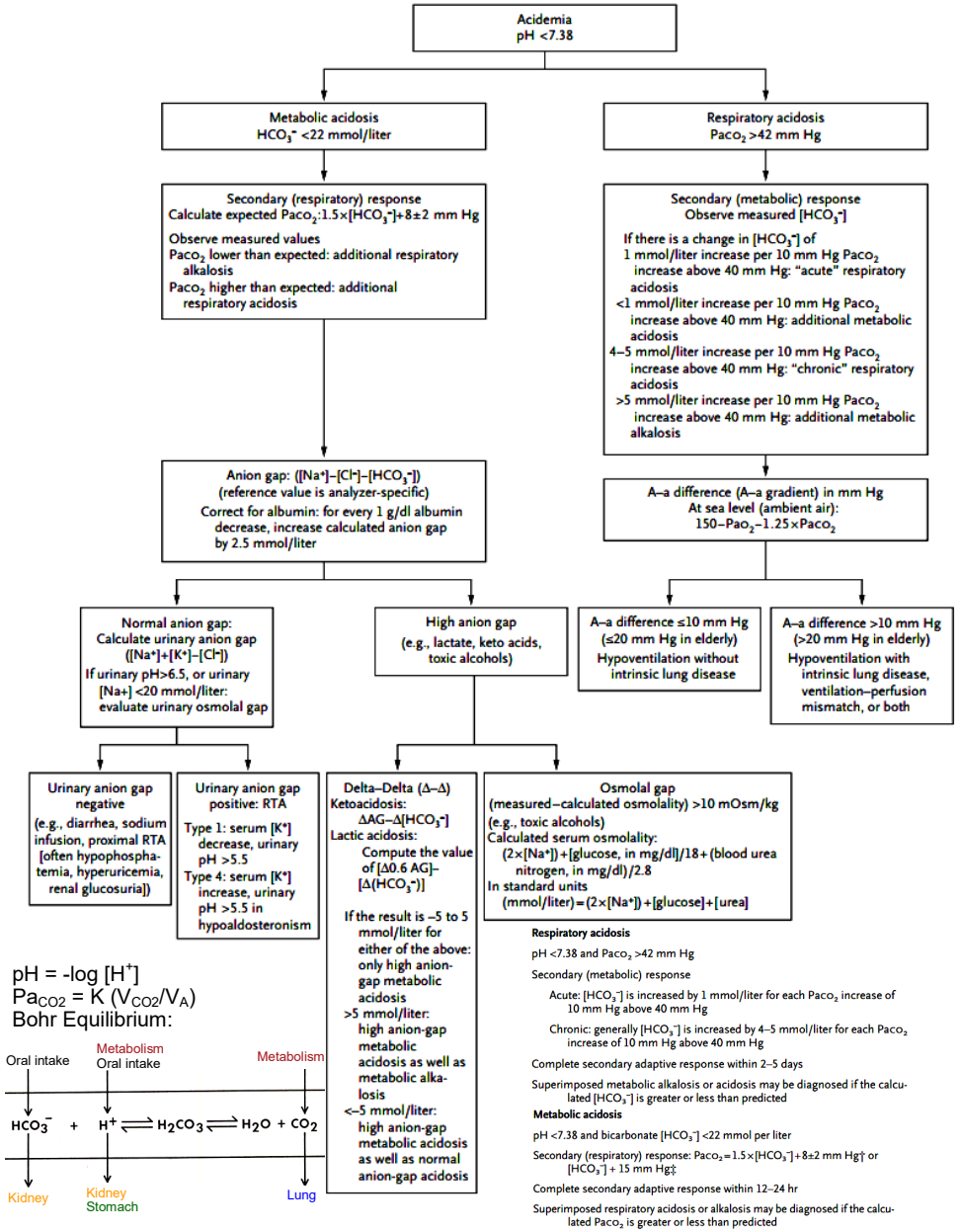
Agent	Equiv. Dose (mg)	Glucocorticoid Potency	Mineralocorticoid Potency	Half Life (hours)
Cortisone	25	0.8	0.8	8-12
Hydrocortisone	20	1	1	8-12
Prednisone	5	4	0.8	18-36
Methylprednisone	5	5	0.5	18-36
Dexamethasone	0.75	25	0	36-54

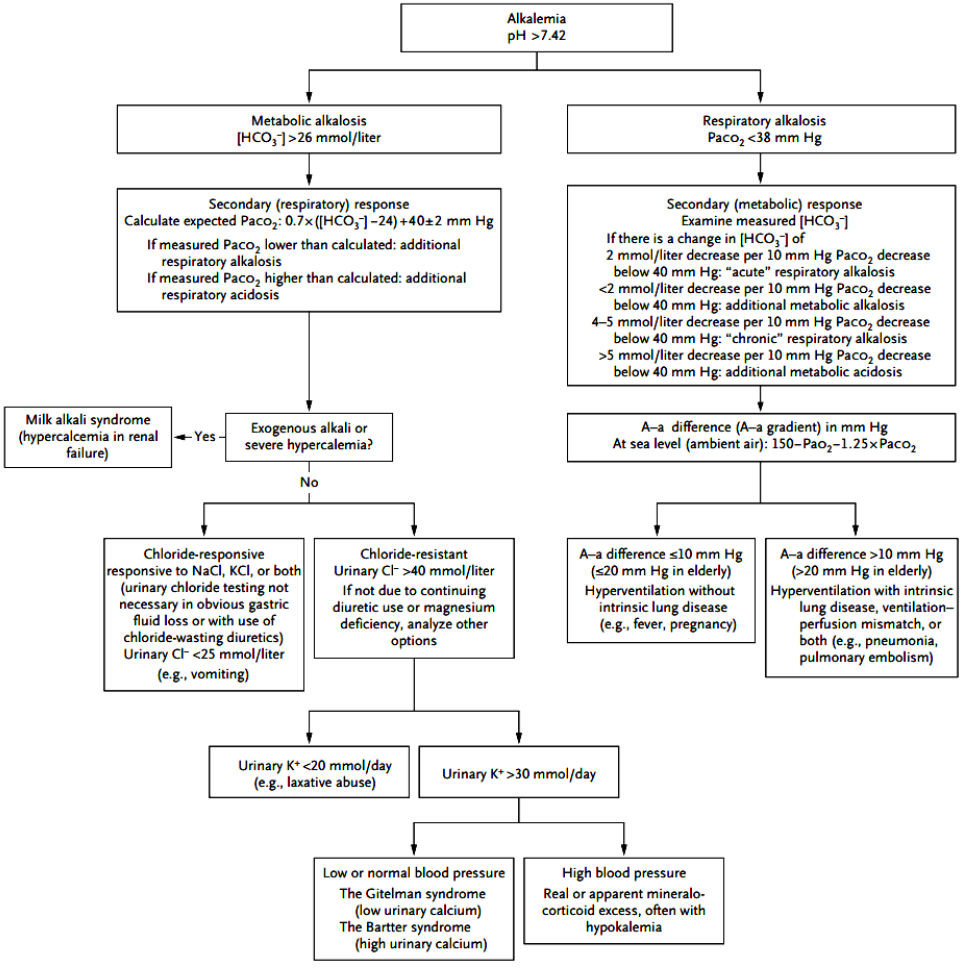
EXTUBATION READINESS TESTING

Patient Factors	Is respiratory failure reversed? Is vent set low enough? Is patient awake? Are sedatives reduced? Is patient strong enough? Protect their airway? Are secretions a problem? Is there an ETT leak? Would Dexamethasone be appropriate? Is the patient NPO?
Equipment	Bedside suction (Yankouer, soft suction, deep suction)? Oral Airways? Bag and mask w/O_2 flowing? Towels to position patient? Appropriate medications drawn up? Re-intubation supplies? Special airway (LMA, glidescope)? Nurse, RT, parents notified? Anesthesia or ENT notified is appropriate?

RESPIRATORY




Acidemia
pH <7.38
Metabolic acidosis
HCO_3^- <22 mmol/liter
Respiratory acidosis
$Paco_2$ >42 mm Hg
Secondary (respiratory) response
Calculate expected $Paco_2$:1.5×[HCO_3^-]+8±2 mm Hg
Observe measured values
$Paco_2$ lower than expected: additional respiratory alkalosis
$Paco_2$ higher than expected: additional respiratory acidosis
Secondary (metabolic) response
Observe measured [HCO_3^-]
If there is a change in [HCO_3^-] of
1 mmol/liter increase per 10 mm Hg $Paco_2$ increase above 40 mm Hg: "acute" respiratory acidosis
<1 mmol/liter increase per 10 mm Hg $Paco_2$ increase above 40 mm Hg: additional metabolic acidosis
4–5 mmol/liter increase per 10 mm Hg $Paco_2$ increase above 40 mm Hg: "chronic" respiratory acidosis
>5 mmol/liter increase per 10 mm Hg $Paco_2$ increase above 40 mm Hg: additional metabolic alkalosis
Anion gap: ([Na^+]–[Cl^-]–[HCO_3^-])
(reference value is analyzer-specific)
Correct for albumin: for every 1 g/dl albumin decrease, increase calculated anion gap by 2.5 mmol/liter
A–a difference (A–a gradient) in mm Hg
At sea level (ambient air):
$150-Pao_2-1.25\times Paco_2$
Normal anion gap:
Calculate urinary anion gap ([Na^+]+[K^+]–[Cl^-])
If urinary pH>6.5, or urinary [Na+] <20 mmol/liter: evaluate urinary osmolal gap
High anion gap
(e.g., lactate, keto acids, toxic alcohols)
A–a difference ≤10 mm Hg (≤20 mm Hg in elderly)
Hypoventilation without intrinsic lung disease
A–a difference >10 mm Hg (>20 mm Hg in elderly)
Hypoventilation with intrinsic lung disease, ventilation–perfusion mismatch, or both
Urinary anion gap negative
(e.g., diarrhea, sodium infusion, proximal RTA [often hypophosphatemia, hyperuricemia, renal glucosuria])
Urinary anion gap positive: RTA
Type 1: serum [K^+] decrease, urinary pH >5.5
Type 4: serum [K^+] increase, urinary pH >5.5 in hypoaldosteronism
Delta–Delta (Δ–Δ)
Ketoacidosis:
$\Delta AG-\Delta[HCO_3^-]$
Lactic acidosis:
Compute the value of [Δ0.6 AG]–[Δ(HCO_3^-)]
If the result is –5 to 5 mmol/liter for either of the above: only high anion-gap metabolic acidosis
>5 mmol/liter: high anion-gap metabolic acidosis as well as metabolic alkalosis
<–5 mmol/liter: high anion-gap metabolic acidosis as well as normal anion-gap acidosis
Osmolal gap
(measured–calculated osmolality) >10 mOsm/kg
(e.g., toxic alcohols)
Calculated serum osmolality:
(2×[Na^+])+[glucose, in mg/dl]/18+(blood urea nitrogen, in mg/dl)/2.8
In standard units
(mmol/liter) = (2×[Na^+])+[glucose]+[urea]
pH = -log [H^+]
$Pa_{CO2} = K (V_{CO2}/V_A)$
Bohr Equilibrium:
Oral intake
Metabolism
Oral intake
Metabolism
HCO_3^- + H^+ ⇌ H_2CO_3 ⇌ H_2O + CO_2
Kidney
Kidney
Stomach
Lung
Respiratory acidosis
pH <7.38 and $Paco_2$ >42 mm Hg
Secondary (metabolic) response
Acute: [HCO_3^-] is increased by 1 mmol/liter for each $Paco_2$ increase of 10 mm Hg above 40 mm Hg
Chronic: generally [HCO_3^-] is increased by 4–5 mmol/liter for each $Paco_2$ increase of 10 mm Hg above 40 mm Hg
Complete secondary adaptive response within 2–5 days
Superimposed metabolic alkalosis or acidosis may be diagnosed if the calculated [HCO_3^-] is greater or less than predicted
Metabolic acidosis
pH <7.38 and bicarbonate [HCO_3^-] <22 mmol per liter
Secondary (respiratory) response: $Paco_2 = 1.5\times[HCO_3^-]+8\pm2$ mm Hg† or [HCO_3^-]+15 mm Hg‡
Complete secondary adaptive response within 12–24 hr
Superimposed respiratory acidosis or alkalosis may be diagnosed if the calculated $Paco_2$ is greater or less than predicted



Respiratory alkalosis

pH >7.42 and $Paco_2$ <38 mm Hg

Secondary (metabolic) response

Acute: $[HCO_3^-]$ is decreased by 2 mmol/liter for each $Paco_2$ decrease of 10 mm Hg below 40 mm Hg

Chronic: $[HCO_3^-]$ is decreased by 4–5 mmol/liter for each $Paco_2$ decrease of 10 mm Hg below 40 mm Hg

Complete secondary adaptive response in 2–5 days

Superimposed metabolic alkalosis or acidosis may be diagnosed if the calculated $[HCO_3^-]$ is greater or less than predicted

Metabolic alkalosis

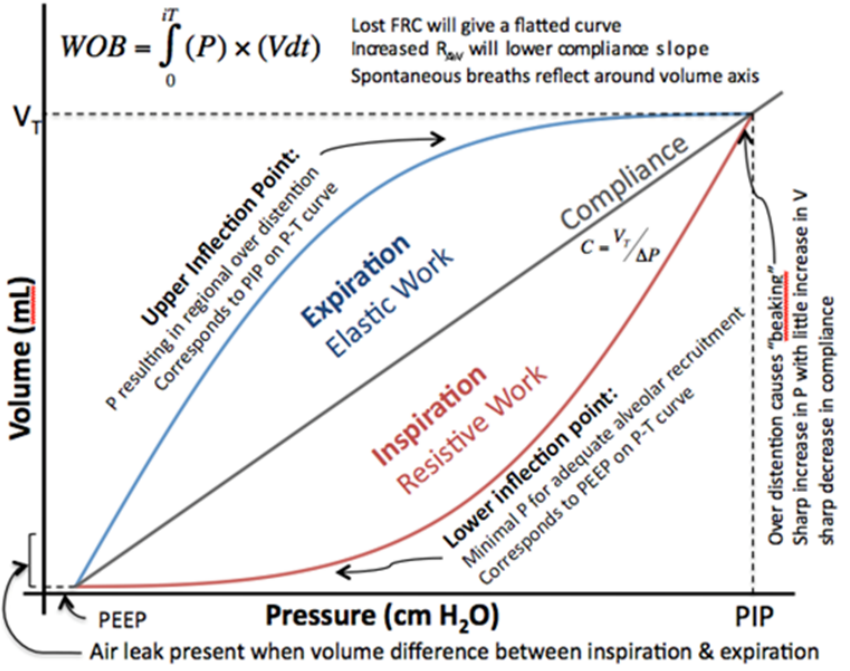
pH >7.42 and $[HCO_3^-]$ >26 mmol per liter

Secondary (respiratory) response: $Paco_2 = 0.7 \times ([HCO_3^-] - 24) + 40 \pm 2$ mm Hg or $[HCO_3^-] + 15$ mm Hg; or $0.7 \times [HCO_3^-] + 20$ mm Hg

Complete secondary adaptive response within 24–36 hr

Superimposed respiratory acidosis or alkalosis may be diagnosed if the calculated $Paco_2$ is greater or less than predicted

Super Important Pulmonary Equations		
Compliance: C = ΔV/ΔP; Elastance: E = ΔP/ΔV		
Ohm's Law: Flow = ΔP/R and Poiseulle: R=(8nl)/(πr4)		
A-a Gradient = [(FiO2)(P_{atm}-P_{H2O}) – (PaCO2/0.8)] – PaO2 (nl <15) Estimate: (Proj PaO2=7(FiO2 – PaCO2))		
Newton's Resp Eq of Motion: P_{RS}=P_{AO}-P_{MUS}=V_T/C_R+(V̇)(R) +PEEP		
Dead Space Ratio: V_D/V_T = (PaCO2 – Et CO2)/(PaCO2)		
OI = (FiO2)(MAP)/(PaO2) (Resp failure >12, HFOV or ECMO >30)		
$P_aCO_2 \approx P_ACO_2 = (V_{CO2})/(V_E) = [(RQ)(VO_2)]/[f(V_T-V_D)]$		
Mean Airway Pressure = (PIP – PEEP) x (Ti / Ttot) + PEEP		
V_T = 5 to 7 $^{ml}/_{kg}$ **V_D =2 to 3 $^{ml}/_{kg}$** **V_C = 65 to 75 $^{ml}/_{kg}$**	**$C_{DYN} = (V_T – V_D)/PIP – PEEP$** **$C_{STAT} = (V_T – V_D)/P_{PLAT} – PEEP$**	**Min Vent = (RR)(V_T)** **Alv Vent = (RR)(V_A)** **Ƭ=(R)(C)**



Vital Cap.	Respiratory Pathology	Ventilator Management
70-45 $^{mL}/_{kg}$	Normal	None
45-25 $^{mL}/_{kg}$	Poor cough, ↑ secretions,	Chest physiotherapy, IS
15-25 $^{mL}/_{kg}$	Poor sigh, ↑ atelectasis, hypoemia, ↑ shunt	HFNC, elective intubation
< 15 $^{mL}/_{kg}$	Hypoventilation, hypoxia, hypercapnea	PPV to full mechanical support

MECHANISM OF HYPOXEMIA	
Hypoventilation	Abnormal respiratory mechanics, normal A-a Abnormal central respiratory control
Ventilation-Perfusion mismatch	Most common cause of hypoxemia **$V/Q = [8.63(R)(CaO_2 – CmvO_2)] / P_ACO_2$**
Shunting of pulmonary blood	Shunt >30% does not respond to increased FiO_2
Diffusion restriction	Increased A-a gradient

PARDS DEFINITION AND MANAGEMENT			
PARDS	**Mild**	**Moderate**	**Severe**
Non– invasive vent. **P/F < 300, S/F < 264**	Invasive Vent. **OI: 4-8, OSI: 5-7.5**	Invasive Vent. **OI: 8-16, OSI: 7.5-12.3**	Invasive Vent. **OI: >16, OSI >12.3**
1. Onset within 7 days of insult. **2.** Respiratory failure not explained by cardiac failure or fluid overload. **3.** New infiltrates on CXR consistent with pulmonary parenchymal disease Wean FiO2 to saturation of <97% to obtain S/F ration or OSI			
VT: 6-10 mL/kg with PaCO2 65-85 if pH > 7.15 and no ICP , **PPLAT**: < 30 cm H2O to minimize barotraumas, **PEEP**: 10-15 cm H2O: (higher if diffuse lung injury) **FiO2**: 60-80% Tolerate PaO240-60, SpO2 85-95%			

Conventional Mechanical Ventilator Management

Oxygenation
PaO2 50-80 mmHg
AND/OR
SpO2 85-92%

Assure exhaled Vt=6 mL/kg PBW AND Pplat≤30 cmH2O

Ventilation
pH 7.25-7.45
(allow permissive hypercapnia)

If PaO2<50 mmHg OR SpO2<85%

If PaO2>80 mmHg or SpO2>95%

Increase PEEP/FiO2 per chart

Decrease PEEP/FiO2 per chart

FiO2	0.30	0.40	0.40	0.50	0.50
PEEP	5	6	8	8	10
FiO2	0.60	0.70	0.70	0.70	0.80
PEEP	10	10	12	14	14
FiO2	0.90	0.90	0.90	1.0	1.0
PEEP	14	16	18	18	20

If OI is 20 and rising, transition to HFOV (OI=100 X MAP X FiO2/PaO2)

Volume Recruitment Maneuver with suctioning or disconnects: sustained inflation (30-40 s) at higher pressures (30-40 cmH2O)

If pH<7.25

If pH>7.45

Increase ventilator rate by 2-4 bpm q 30 min until pH>7.25

Decrease ventilator rate by 2-4 bpm q 0.5-1 h to a minimum of 8 bpm while maintaining respiratory rate goal

Respiratory Rate Goal
<6 mos 20-60
6 mos-2 yrs 15-45
2-5 yrs 15-40
>5 yrs 10-35

Accept lower pH OR if pCO2<32 may give NaHCO3 (1 mEq/kg) to buffer pH>7.25 OR may increase Vt to 8 mL/kg in 1 mL/kg steps (Pplat goal may be exceeded)

Switch straight to CPAP + PS (Minimal PS + 2 cmH2O to maintain Vt at 6 mL/kg

Minimal PS
10 cmH2O if 3-3.5 mm ETT
8 cmH2O if 4-4.5 mmETT
6 cmH2O if ≥ 5 mmETT

HIGH FREQUENCY OSCILLATORY VENTILATION

MAP: 15-30 cmH_2O to recruit ~7-9 ribs on CXR (typically 2-8 cmH2O higher than CV)
I:E Ratio: 1:3 to 1:1 (1:1 more appropriate with diffuse lung injury), **FiO2**: 60-80%
ΔP: Typically 2-7 cmH2O as determined by PCO2
Bias Gas Flow: Flow of gas that removes CO2 and adds O_2 to circuit: >18L/min

Starting Amplitude achieve visible chest vibrations		**Starting Frequency** 3-15 Hz, lower in adults, higher in infants			
Infant	40-50 cm H2O	**< 2 kg**	15 Hz	**21-30 kg**	7 Hz
Child	50-60 cm H2O	**2-12 kg**	10 Hz	**>30 kg**	6 Hz
Adult	50-100 cm H2O	**13-20 kg**	8 Hz		

HFOV TITRATION

DECREASE CO2	INCREASE O2
Decrease frequency Increase amplitude Adjust bias flow (A: 20 or B: 30 LPM) Reduce ETT cuff pressure, increase i-time	Increase FiO2 Increase Bias flow Increase MAP Increase ETT cuff pressure

Initial Starting Recommendations
Adjust HOB to 30 degrees
MAP: 5-7 cmH2O above conventional ventilator (confirm adequacy by CXR showing 9-10 posterior ribs of expansion
FiO2: 1.0
AMP: increase to achieve adequate chest movement (vibrating up to the abdomen)
% Inspiratory time: 33%
Flow rate: >20 LPM
Frequency: < 2 kg – 15 Hz
2-< 12 kg – 10 Hz
12-< 20 kg – 7 Hz
20-<30 kg – 6 Hz
≥30 kg – 5 Hz
Get an ABG 15 min after initial settings to assess for oxygenation and ventilation.

To Improve Oxygenation

Target FiO2 is 0.6.
Incremental increases in MAP.

To Improve Ventilation

Increase AMP in increments of 5 cmH2O.

If pH is still in respiratory acidosis with ph<7.25 after increasing AMP to maximum settings (100 cmH2O), decrease frequency in increments of 2 Hz and repeat the process. (Minimum is 3 Hz.)

For larger patients (>30 kg), higher flow rates may be needed to achieve MAP or to accomplish ventilation

Weaning from HFOV

For oxygenation: incremental decreases in FiO2 until 0.6, then incremental (1-2 cmH2O) decreases in MAP.

For ventilation: incremental (3-5 cmH2O) decreases in AMP.

Weaning to conventional ventilation can occur when MAP is 15-20 cmH2O and FiO2 is 0.4-0.6.

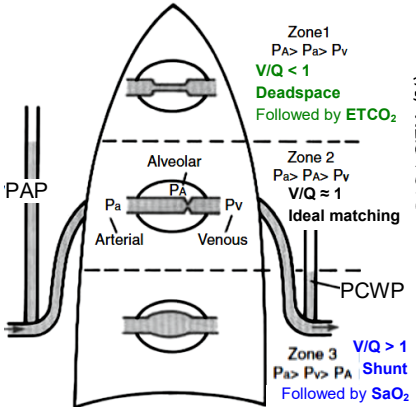
HFPV Trial (VDR Bronchotron)

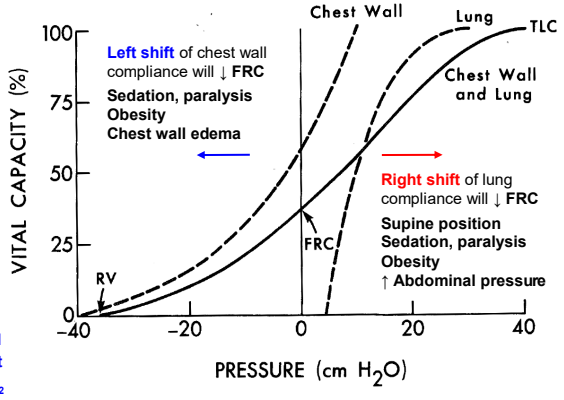
Initial Settings: Keep PIP and PEEP from CMV, Set **Demand PEEP to 4 , Oscillatory PEEP to 10 mmHg**, Adjust I:E to 1:1 to establish **Convective Rate to 12-18 (adults), 15-25 (child), 20-40 (infant),** Set **Pulse Frequency** by adjusting Pulse I/E ratio to **300-700** (keep I:E 1:1). Monitor mean arterial pressure closely.

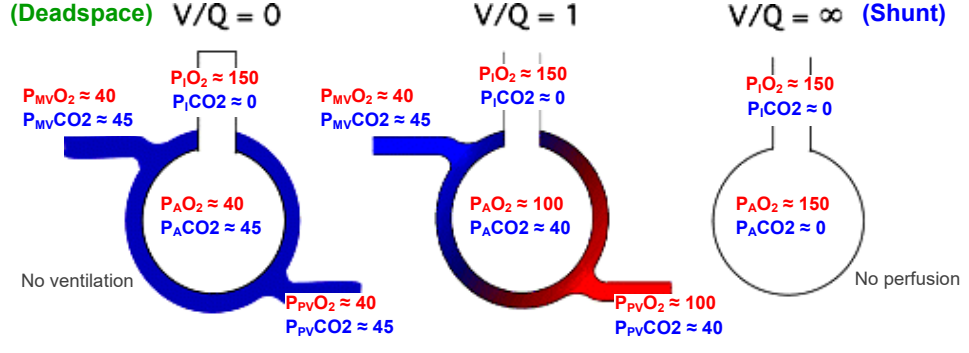
↑ PO_2	↓ PCO_2	↑ Secretions
↑ Oscillatory PEEP ↑ Pulse Frequency ↑ PIP ↓ E-time (2:1 I:E min) Add Convective Pressure rise by 5 Minimize ETT cuff leak	↓ Pulse Frequency ↑ PIP ↑ I-time ↑ Convective rate Add Convective Pressure rise by 5 Allow ETT cuff leak	↓ Pulse Frequency ↑ I-time ↑ Humidity (double heater)

Normal Values for Lung Function								
Age	**1 wk**	**1 yr**	**3 yr**	**5 yr**	**8 yr**	**12 yr**	**18 yr M**	**18 yr F**
FRC (mL)	75	260	530	660	1174	1855	3030	2350
VC (mL)	100	475	910	1100	1855	2830	4620	3380
V_E (mL/min)	550	1775	2460	2600	3240	4150	6000	5030
V_T (mL)	17	78	112	130	180	260	500	420
Rate	30	24	22	20	18	16	12	12
V_A (mL/min)	385	1245	1760	1800	2195	2790	4140	3530
V_D (mL)	75	21	37	49	75	105	150	126
C_1 (mL/cmH_2O)	5	16	32	44	71	91	163	130
Peak flow (L/min)	10	-	-	136	231	325	457	365
R (cmH_2O/L/sec)	29	13	10	8	6	5	2	2
CO (L/min)	0.9	1.9	2.7	3.2	4.4	5.7	7.6	7.2
Lung weight (g)	49	120	166	211	290	470	730	700

Super-Important Random Cardio-Pulmonary Graphs

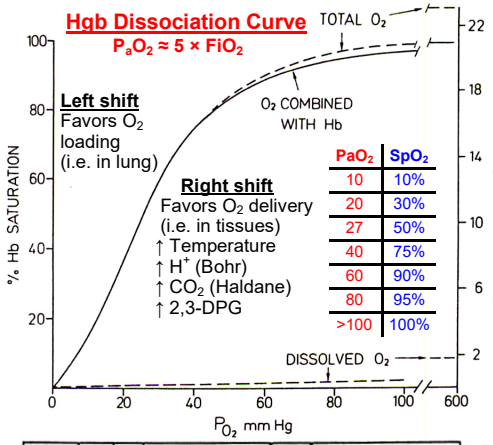






Hgb Dissociation Curve

$P_aO_2 \approx 5 \times FiO_2$

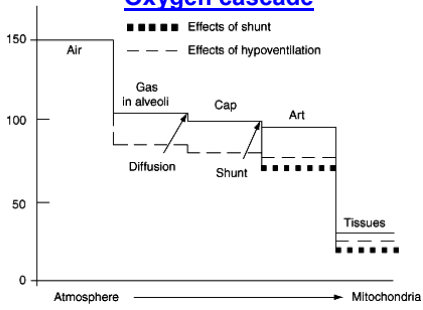


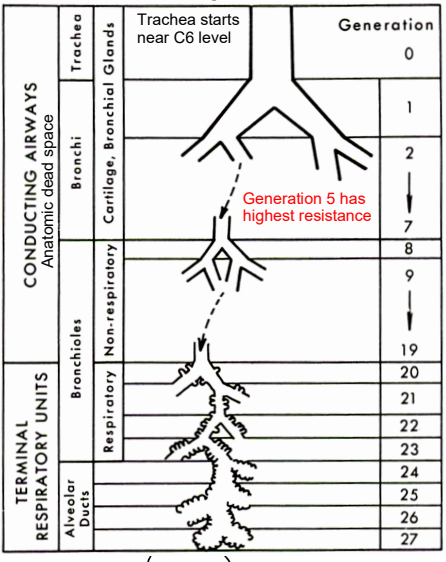
Left shift
Favors O_2 loading
(i.e. in lung)

Right shift
Favors O_2 delivery
(i.e. in tissues)
↑ Temperature
↑ H^+ (Bohr)
↑ CO_2 (Haldane)
↑ 2,3-DPG

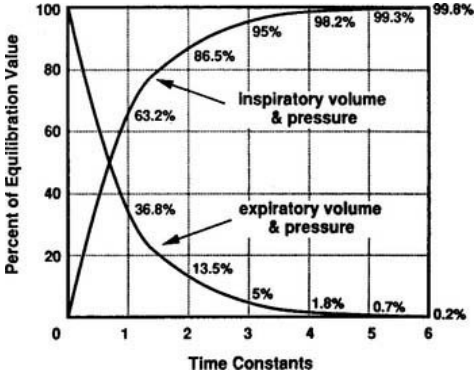
PaO_2	SpO_2
10	10%
20	30%
27	50%
40	75%
60	90%
80	95%
>100	100%

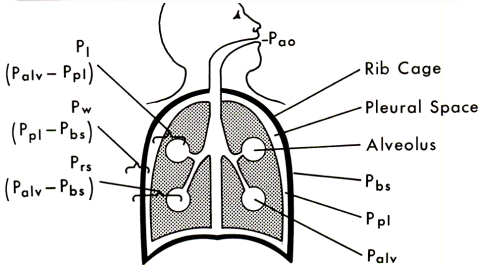
Oxygen cascade



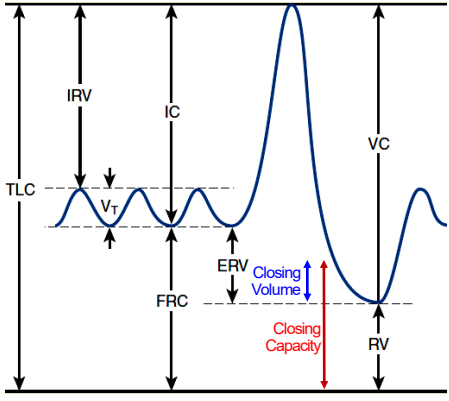


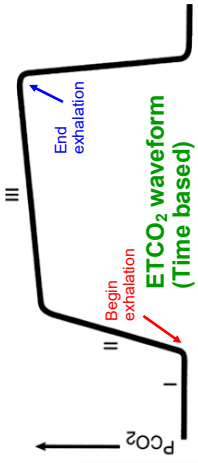
Alveolar time constant: T=(R)(C)

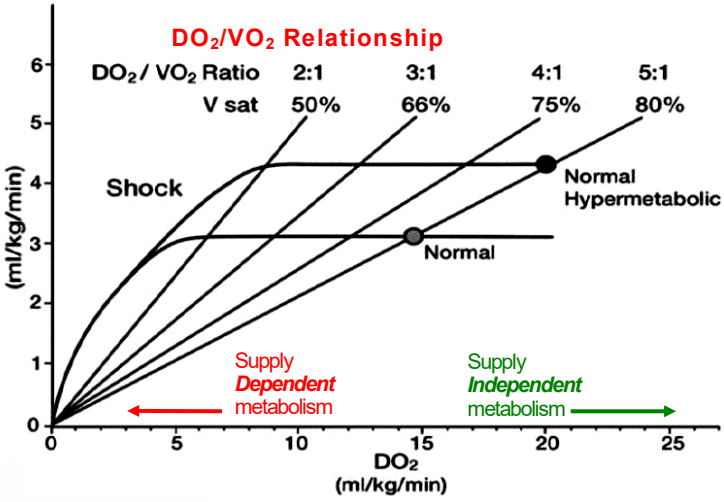


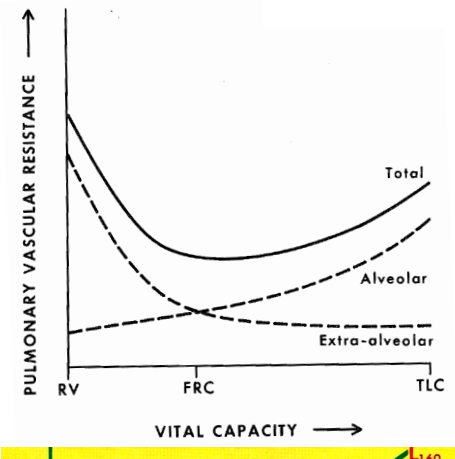


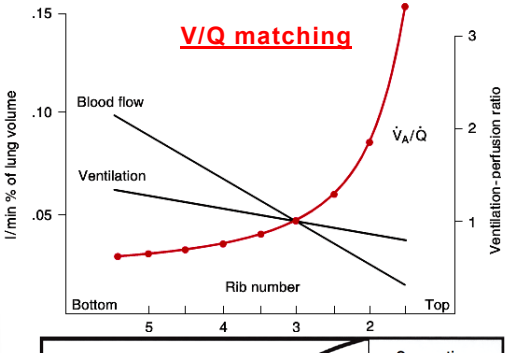
Lung volumes and capacities

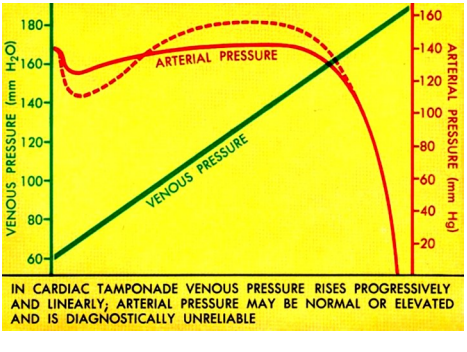


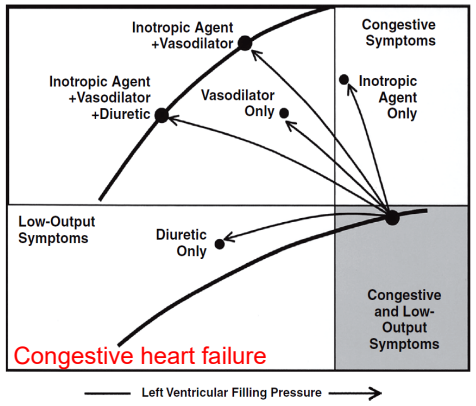

End exhalation
Begin exhalation
ETCO2 waveform (Time based)
PCO2

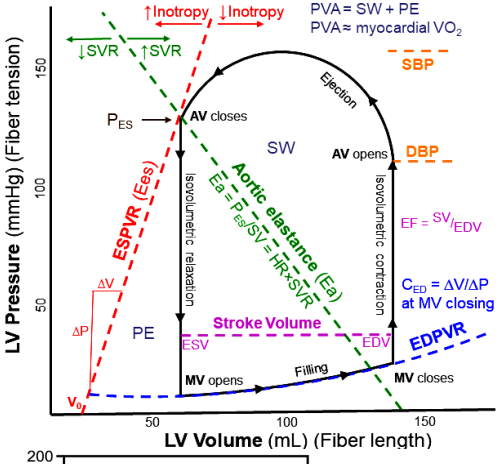

DO2/VO2 Relationship
DO2/ VO2 Ratio 2:1 3:1 4:1 5:1
V sat 50% 66% 75% 80%
Shock
Normal Hypermetabolic
Normal
VO2 (ml/kg/min)
Supply Dependent metabolism
Supply Independent metabolism
DO2 (ml/kg/min)

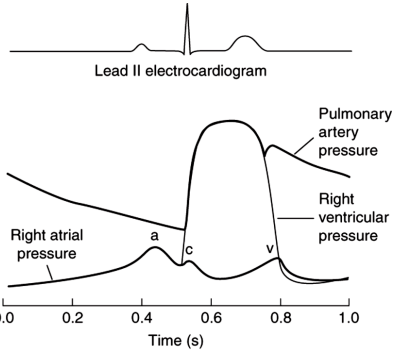

PULMONARY VASCULAR RESISTANCE
Total
Alveolar
Extra-alveolar
RV
FRC
TLC
VITAL CAPACITY

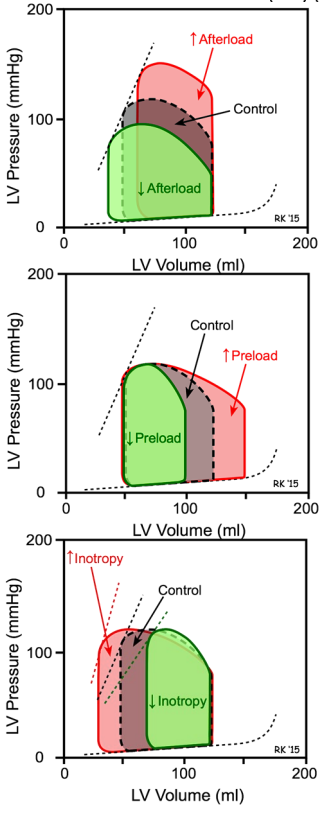

V/Q matching
l/min % % of lung volume
Blood flow
Ventilation
V̇A/Q̇
Ventilation-perfusion ratio
Rib number
Bottom
Top

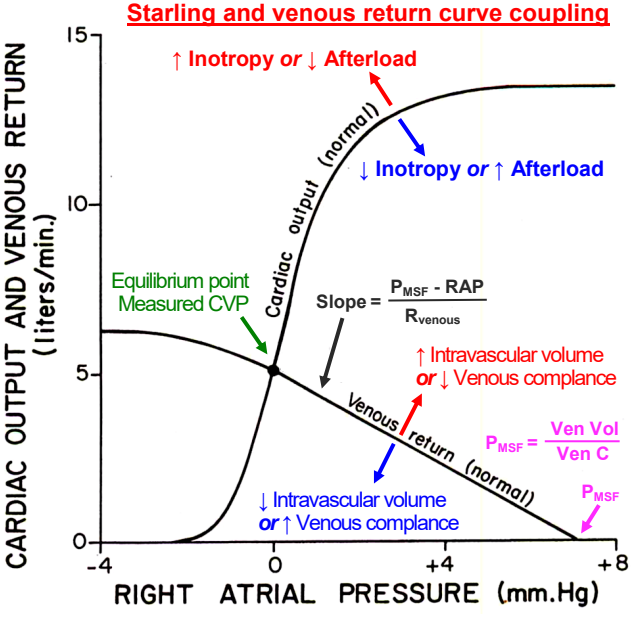

VENOUS PRESSURE (mm H2O)
ARTERIAL PRESSURE
VENOUS PRESSURE
ARTERIAL PRESSURE (mm Hg)
IN CARDIAC TAMPONADE VENOUS PRESSURE RISES PROGRESSIVELY AND LINEARLY; ARTERIAL PRESSURE MAY BE NORMAL OR ELEVATED AND IS DIAGNOSTICALLY UNRELIABLE


Inotropic Agent +Vasodilator
Congestive Symptoms
Inotropic Agent +Vasodilator +Diuretic
Vasodilator Only
Inotropic Agent Only
Low-Output Symptoms
Diuretic Only
Congestive and Low-Output Symptoms
Congestive heart failure
Stroke Volume
Left Ventricular Filling Pressure









Value	Importance	Normal
PAOP	LV filling Pressure	10-15mmHg
SV	Indicates volume status	>1 mL/kg, 50-100 in adults
SI	Indicates contractility	45 mL/m^2
SVR	Peripheral vascular tone	800-1000
DO_2	Oxygen delivery	600-650 ml/min/m^2

Oxygen Consumption Charts

Oxygen Consumption per Body Surface Area*

Age (yr)	Heart Rate (beats/min) 50	60	70	80	90	100	110	120	130	140	150	160	170
Male Patients													
3				155	159	163	167	171	175	178	182	186	190
4			149	152	156	160	163	168	171	175	179	182	186
6		141	144	148	151	155	159	162	167	171	174	178	181
8		136	141	145	148	152	156	159	163	167	171	175	178
10	130	134	139	142	146	149	153	157	160	165	169	172	176
12	128	132	136	140	144	147	151	155	158	162	167	170	174
14	127	130	134	137	142	146	149	153	157	160	165	169	172
16	125	129	132	136	141	144	148	152	155	159	162	167	
18	124	127	131	135	139	143	147	150	154	157	161	166	
20	123	126	130	134	137	142	145	149	153	156	160	165	
25	120	124	127	131	135	139	143	147	150	154	157		
30	118	122	125	129	133	136	141	145	148	152	155		
35	116	120	124	127	131	135	139	143	147	150			
40	115	119	122	126	130	133	137	141	145	149			

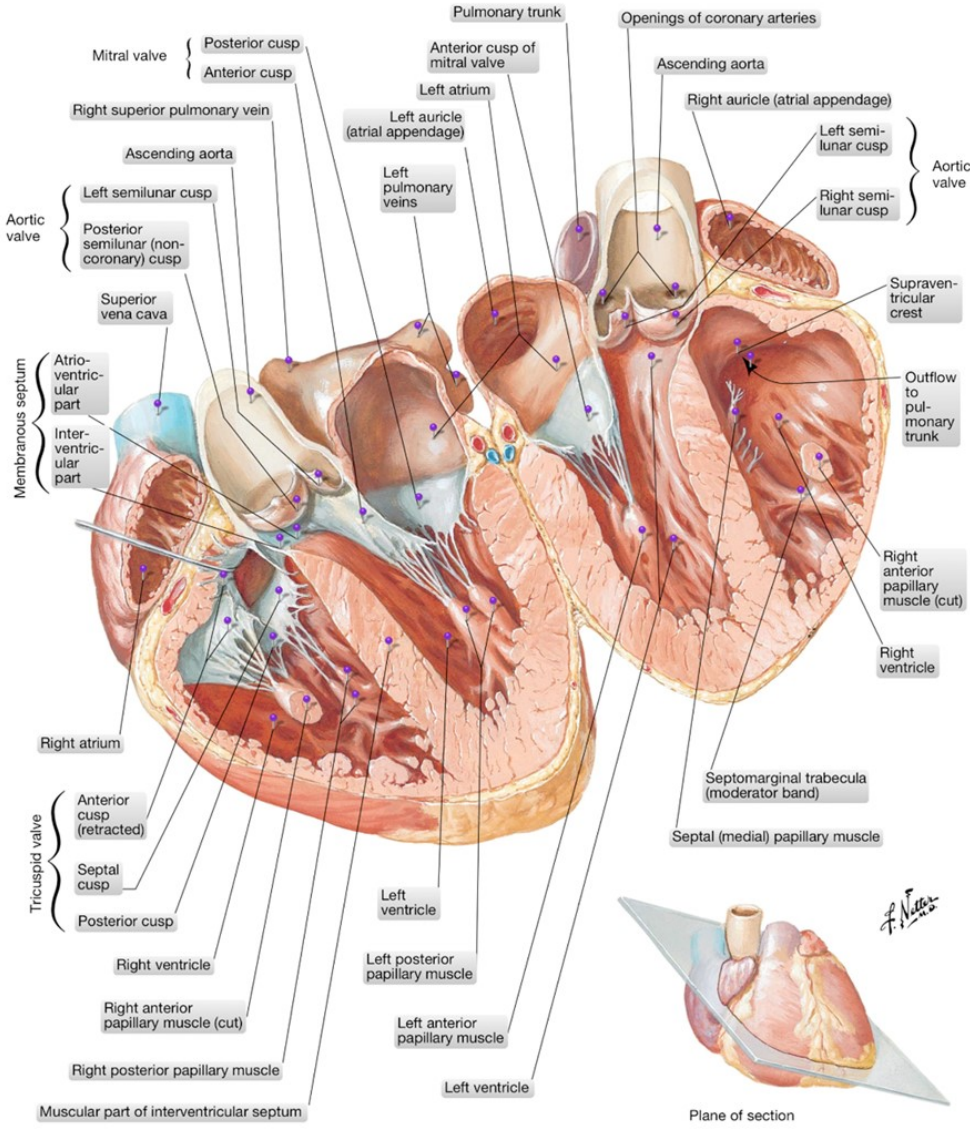
*In (mL/min)/m^2. From LaFarge CG, Miettinen OS: The estimation of oxygen consumption. *Cardiovasc Res* 4:23, 1970. Taken from Park, MK: *Pediatric Cardiology for Practitioners*, 4th ed.

Oxygen Consumption per Body Surface Area*

Age (yr)	Heart Rate (beats/min) 50	60	70	80	90	100	110	120	130	140	150	160	170
Female Patients													
3				150	153	157	161	165	169	172	176	180	183
4			141	145	149	152	156	159	163	168	171	175	179
6		130	134	137	142	146	149	153	156	160	165	168	172
8		125	129	133	136	141	144	148	152	155	159	163	167
10	118	122	125	129	133	136	141	144	148	152	155	159	163
12	115	119	122	126	130	133	137	141	145	149	152	156	160
14	112	116	120	123	127	131	134	133	143	146	150	153	157
16	109	114	118	121	125	128	132	136	140	144	148	151	
18	107	111	116	119	123	127	130	134	137	142	146	149	
20	106	109	114	118	121	125	128	132	136	140	144	148	
25	102	106	109	114	118	121	125	128	132	136	140		
30	99	103	106	110	115	118	122	125	129	133	136		
35	97	100	104	107	111	116	119	123	127	130			
50	94	98	102	105	109	112	117	121	124	128			

*In (mL/min)/m^2. From LaFarge CG, Miettinen OS: The estimation of oxygen consumption.

CARDIOLOGY


Pulmonary trunk
Openings of coronary arteries
Mitral valve
Posterior cusp
Anterior cusp
Anterior cusp of mitral valve
Ascending aorta
Left atrium
Right auricle (atrial appendage)
Right superior pulmonary vein
Left auricle (atrial appendage)
Left semi-lunar cusp
Aortic valve
Right semi-lunar cusp
Ascending aorta
Left pulmonary veins
Aortic valve
Left semilunar cusp
Posterior semilunar (non-coronary) cusp
Supraventricular crest
Superior vena cava
Membranous septum
Atrioventricular part
Interventricular part
Outflow to pulmonary trunk
Right anterior papillary muscle (cut)
Right ventricle
Right atrium
Septomarginal trabecula (moderator band)
Septal (medial) papillary muscle
Tricuspid valve
Anterior cusp (retracted)
Septal cusp
Posterior cusp
Left ventricle
Right ventricle
Left posterior papillary muscle
Right anterior papillary muscle (cut)
Left anterior papillary muscle
Right posterior papillary muscle
Left ventricle
Muscular part of interventricular septum
Plane of section

VENTRICULAR FIBRILLATION
PULSELESS VENTRICULAR TACHYCARDIA

Paddle Size	Infant paddles: Infants <1 yr or <10 kg Adult paddles: Children >1 yr and >10 kg

ALWAYS ASSESS AND SUPPORT ABC'S – INITIATE CPR

IF there is a QRS, Use SYNC Mode

Then up to 3 SHOCKS rapidly: Give sedation/analgesia prior to shocks.
CHILDREN: **2 J/kg, 2 J/kg, 4 J/kg** (Check rhythm after each shock)
ADULTS: **200 J, 300 J, 360 J** (Check rhythm after each shock) **If Rhythm fails to convert after 3 shocks**, continue CPR and begin medicine administration

Medication regimen for VF and pulseless VT
FOLLOW EACH MED DOSE IN 30-60 SECONDS WITH DEFIB 4 J/KG*

	Medicine	Route	Conc.	Dose
1st	**EPINEPHRINE** (give epi every 3-5 min)	**IV, IO** **ETT**	**0.1 mg/mL** **1 mg/mL**	**0.01 mg/kg** (1 mg max) **0.1 mg/kg**
Then	**LIDOCAINE** Lidocaine drip	IV, IO, ETT	5 to 20 mg/mL	1 mg/kg (300mg max) drip: 20-40 mcg/kg/min
OR	**AMIODARONE** (consult cardiology)	IV, IO	2 mg/mL to 50 mg/mL in D_5W	5mg/kg load (Adults:150mg, 300mg max)
OR	**MAGNESIUM** (Torsade's, VT with low Mg)	IV, IO		$MgSO_4$: 25-50 mg/kg (max 2 g)

Pattern repeats: DRUG, SHOCK, DRUG, SHOCK, DRUG, SHOCK…

***ADULTS: FOLLOW EACH MED DOSE IN 30-60 SEC WITH DEFIB 360 J**

Adult Doses: **Epinephrine** 1 mg (in 10 mL); **Vasopressin** 40 Units
Amiodarone 300 mg, **Lidocaine** 100 mg, **Magnesium** 2 grams

SUPRAVENTRICULAR TACHYCARDIA

Infants HR usually >220; Children HR usually >180

Consult cardiology. Continuous ECG. Attempt Vagal Maneuvers (Ice Bag over Face, Gag, etc.) – Do not delay shocks if unstable. If vagal maneuvers fail, proceed to:

STABLE	**ADENOSINE**: 0.1 mg/kg (max 6 mg) rapid IVP with stopcock and rapid flush. May double (max 12 mg) and repeat dose once only. Prepare for cardioversion. (↑ action with Tegretol, ↓ with theophylline/caffeine)
UNSTABLE	**SYNCHRONIZED CARDIOVERSION (SYNC mode)** – Initial **0.5 to 1 J/kg**. Second and subsequent shocks: **2 J/kg (Adult 100-360 J)**. Give sedation if possible, but do not delay shocks. Support ABCs.

STABLE VENTRICULAR TACHYCARDIA

Consult cardiology. Obtain ECG. Give **Lidocaine** and/or **Amiodarone** at above doses. Prepare for cardioversion. Identify and treat etiology.

BRADYCARDIA

Assess and support ABCs, obtain vascular access, attach monitor
Consider Hypoxia, Hypovolemia, Glu/Lytes, Head injury, Heart block, Toxins/Drugs,
CHEST COMPRESSIONS if HR <60 (infants), <40 (children) with signs of poor systemic perfusion is present
Epinephrine IV,IO: **0.01 mg/kg**, (0.1 mL/kg of 1:10,000) Repeat every 3-5 min
OR ETT: **0.1 mg/kg**, (0.1 mL/kg of 1:1,000, followed by 5 mL NS flush and 5 BMV)
Atropine (AV block or ↑ vagal tone): IV/IO/ETT 0.02 mg/kg (min 0.1 mg, max 0.5 mg child, 1 mg adult) (may repeat atropine only once)

ASYSTOLE / PEA

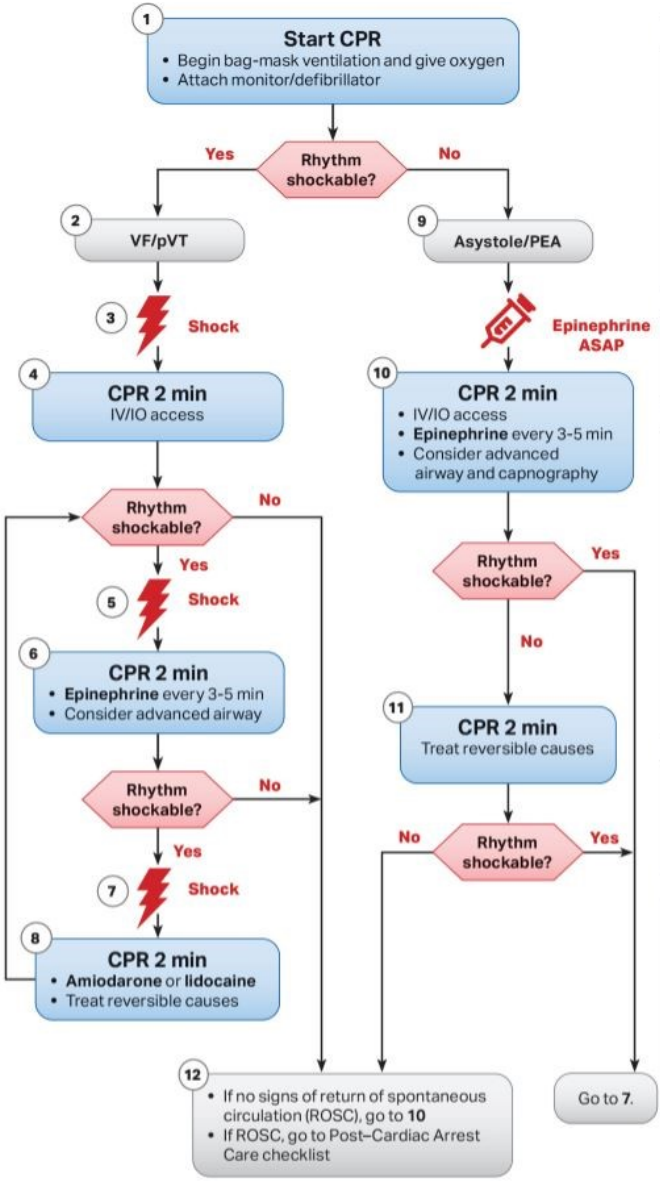
These rhythms should not be shocked
Assess and support ABCs, obtain vascular access, attach monitor, **CPR**, NS bolus
Consider Hypoxia, Hypovolemia, Glu/Lytes, Head injury, Heart block, Toxins/Drugs, pneumothorax, tamponade, thromboembolism. Send blood gas, lytes, iCal,
Epinephrine IV,IO: **(1:10,000)** 0.1 mL/kg (0.01 mg/kg); Repeat every 3-5 minutes
ETT: **(1:1000)** 0.1 mL/kg (0.1 mg/kg, followed by 5 mL NS flush and 5 BMV)

CARDIOVASCULAR MEDICATION

$CaCl_2$	2.5-20 mg/kg/hr	For ↓ Ca or sick heart; no ↑ HR
Dopamine	2-20 mcg/kg/min	Distributive or cardiogenic shock (**D>b>a**) Less active in alkaline solutions ($NaHCO_3$)
Dobutamine	2-20 mcg/kg/min	Hypotension; ↑ HR, ↓ myocardial VO_2
Epinephrine	0.02-1 mcg/kg/min	Resistant cold shock, dilates coronary, ↑ glu, ↓ GI perfusion, bronchodilator.
Lidocaine	20-40 mcg/kg/min	Follow levels q 12-24 hrs
Milrinone	0.3-0.75 mcg/kg/min	Hypotension, renal clearance, hepatoxicity
Nitroprusside	0.2-10 mcg/kg/min	Check thiocyanate levels
Norepinephrine	0.02-2 mcg/kg/min	Resistant warm shock (**a_1=a_2>b_1**)
Phenylephrine	0.1-0.5 mcg/kg/min	Pure Vasoconstrictor
Vasopressin	0.01-0.05 units/kg/hr	Useful if adrenergic side effects (↑ HR) or heart failure; check vasopressin level
Atropine	0.02 mg/kg (min 0.1 mg)	Blocks M_2 receptors: ↑ HR, M_3 receptors: ↓ secretions, sweating and mydriasis

Drug	α_1	β_1	β_2	D	Clinical effect
Phenylephrine	**+++**	**0**	**0**	**0**	↑↑ SVR, ↑/↓ CO, ↑/↓ HR, ↑ smooth muscle
Norepinephrine	**+++**	**++**	**0**	**0**	↑↑ SVR, ↓/↑ CO, ↓/↑ HR
Epinephrine	**+++**	**+++**	**++**	**0**	↑↑ CO, ↓ SVR (↑ SVR at high dose), ↑↑ HR
Dopamine 0.5-2	**0**	**+**	**0**	**++**	↑ CO, ↑/↓ HR
Dopamine 5-10	**+**	**++**	**0**	**++**	↑ CO, ↑ SVR, ↑ HR
Dopamine 10-20	**++**	**++**	**0**	**++**	↑ CO, ↓ SVR, ↑ HR
Dobutamine	**0/+**	**+++**	**++**	**0**	↑ CO, ↓ SVR, ↑↓ HR
Isoproterenol	**0**	**+++**	**+++**	**0**	↑CO, ↓ SVR, ↑↑ HR, relax smooth muscle
Propranolol	**0**	**---**	**---**	**0**	↓ CO, ↓ HR, ↓ GI bleeding
Metoprolol	**0**	**---**	**0/-**	**0**	↓ CO, ↓ HR, ↓ CO, ↓ inotropy

P A L S— 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

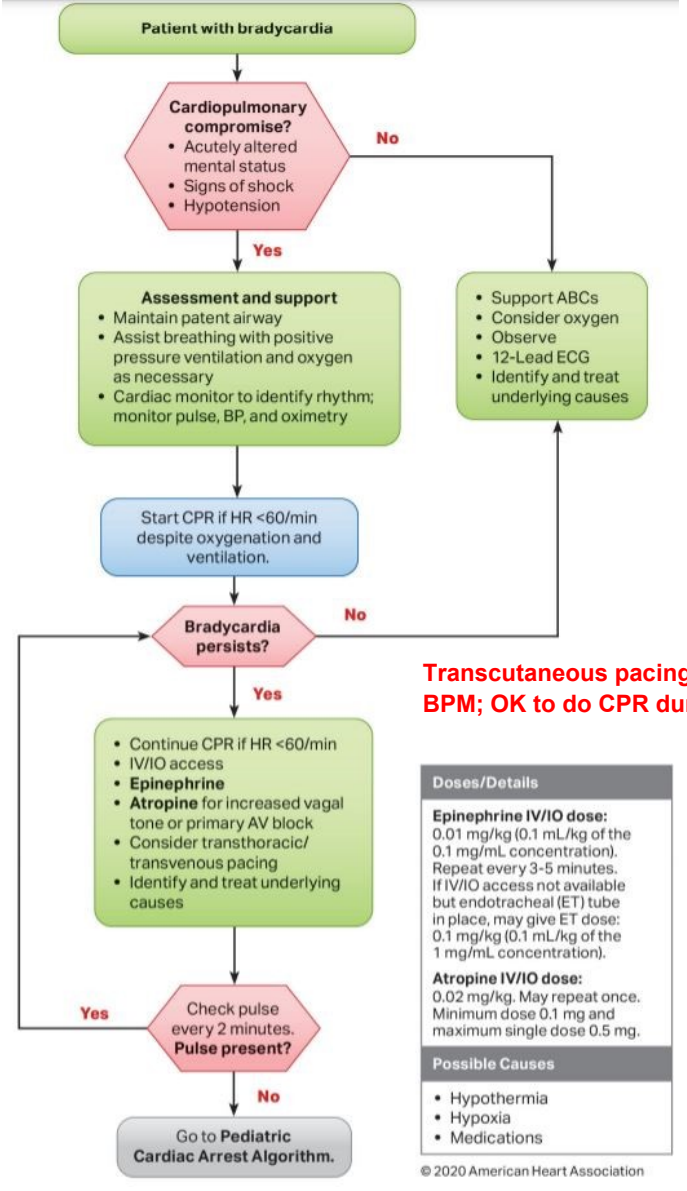
Advanced Airway

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

Reversible Causes

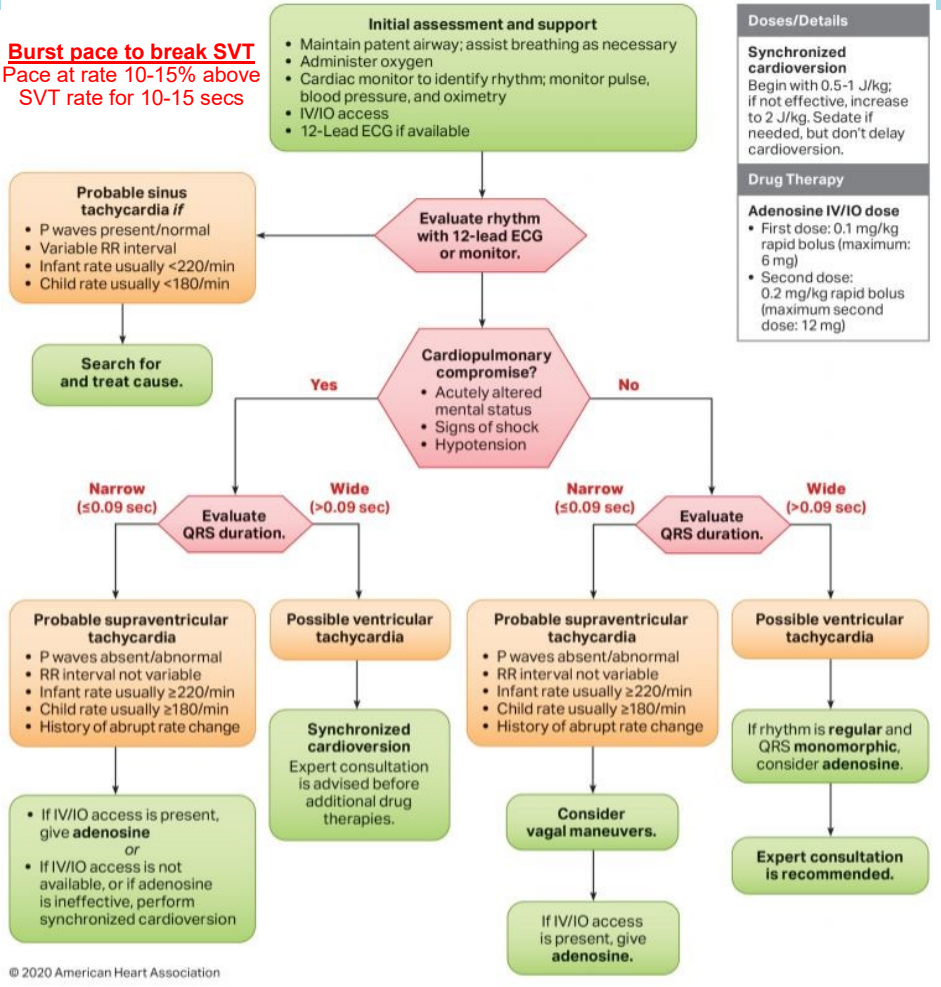
- **H**ypovolemia
- **H**ypoxia
- **H**ydrogen ion (acidosis)
- **H**ypoglycemia
- **H**ypo-/hyperkalemia
- **H**ypothermia
- **T**ension pneumothorax
- **T**amponade, cardiac
- **T**oxins
- **T**hrombosis, pulmonary
- **T**hrombosis, coronary

P A L S —Pediatric Bradycardia With a Pulse Algorithm



Transcutaneous pacing: 30-80 mA at 100 BPM; OK to do CPR during pacing

P A L S —Pediatric Tachycardia With a Pulse Algorithm



SUPER Important Cardiology Equations

Ohm's Law: $Q = \Delta P / R$

Law of Laplace: Tension (Afterload) $= (P_{TM} \times r) / (2 \times \text{thickness})$

Oxygen extraction ratio: $OER = VO_2/DO_2 = (SaO_2\text{-}SmvO_2)/SaO_2$

$$DO2 = CO \times CaO2$$

$$DO2 = (HR \times SV) \times (1.34 \times Hgb \times SaO2 + PaO2 \times 0.003), \text{ normal} \approx 500 \ {}^{mL\ O2}/_{min}$$

Mind the units: ${}^{mL\ O2}/_{min} = ({}^{beat}/_{min} \times {}^{mL}/_{beat}) \times ({}^{mL\ O2}/_{g\ Hgb} \times {}^{g\ Hgb}/_{dL} \times \% + mmHg \times {}^{mL\ O2}/_{dL \times mmHg})$

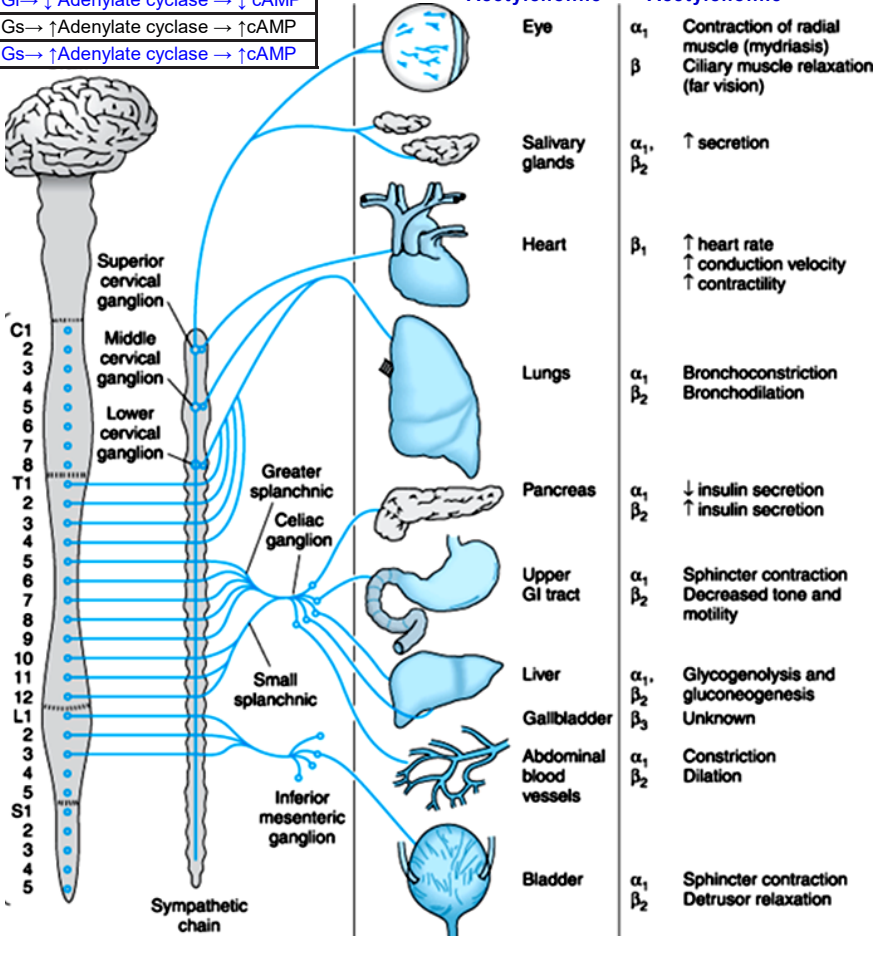
Hypertensive Emergency

Chem10, CBC, UA, UPreg, UTox, EKG, ECHO, 4 ext. BPs, Renal U/S, Neuro/eye exam.
Goal to decrease BP by 25% quickly then to >99th percentile over 24 to 48 hrs
Nitroprusside: 0.3 mcg/kg/min (max 10), **Nicardipine:** 0.5 mcg/kg/min (max 5 mcg/kg/min)
Hydralazine IV or IM: 0.1 to 0.6 mg/kg (max 20 mg/dose) q4 or q6, **Furosemide IV:**1 mg/kg
Labetalol: 0.2-1 mg/kg bolus (max 40 mg) then 0.2 mg/kg/hr (max 3 mg/kg/hr),
Esmolol: 100-500 mcg/kg bolus over 2 min then 50-500 mcg/kg/min (max 1mg/kg/min).

Isradapine PO**:** 0.05-0.1 mg/kg (max 5mg) q8, **Nifedipine** PO**:**0.1-0.25 mg/kg (max 10mg) q4
Hydralazine PO**:** 0.25mg/kg (max 20mg) q6, **Captopril** PO:0.05 mg/kg (max 6mg/kg/d)

ADRENERGIC RECEPTOR TYPES	
α1	Gq→ ↑PLC→↑IP3→↑DAG→↑$Ca2^+$
α2	Gi→ ↓ Adenylate cyclase → ↓ cAMP
β1	Gs→ ↑Adenylate cyclase → ↑cAMP
β2	Gs→ ↑Adenylate cyclase → ↑cAMP

Sympathetic Neurotransmitters
Acetylcholine —> Norepinephrine
Parasympathetic Neurotransmitters
Acetylcholine —> Acetylcholine



NORMAL INTRA-CARDIAC PRESSURES

	Newborn	Child	Adult	L→R shunt	R→L shunt
RAP mean	0 – 4	2 – 6	0 – 8	5	0 – 2
RVP	65-80 / 0-6	15-23 / 3-7	25-30 / 0-8	25/5	110/8
Pulm Art	65-80 / 35-50	15-23 / 10-16	15-30 / 6-12	18-20 / 8-10	20 / 8
Pulm Wedge	6 – 9	8 – 11	4 – 12	2	3 – 8
LA mean	0 – 6	5 – 10	4 – 12	8	2
LV	65-80 / 0-6	90-110 / 7-9	100-130 / 4-12	100 / 8	96 / 8
Aorta	65-80 / 45-60	90-110 / 65-75	100-130 / 60-90	140 / 80	96 / 8
CVP	0 – 8	2 – 6	0 - 8	5	0 - 2

NORMAL QRS VALUES

Each large square= 0.2 sec (#Boxes:HR = 1:300, 2:150, 30:100, 5:60, 6:50)

Age Grp.	HR (bpm)	QRS Vector	PR interv.	QRS duration	Q_{III} mm	QV_6 mm	RV_1 mm	SV_1 mm	R/S V_1 mm	RV_6 mm	SV_6 mm	R/S V_6 mm	SV_1+ RV_6	R+ SV_4
<1 day	93-154 (123)	59-163 (137)	.08-.16 (.11)	.031-.075 (.051)	4.5	2	5-26 (14)	0-23 (8)	.1-U (2.2)	0-11 (4)	0-9.5 (3)	.1-U (2.0)	28	52.5
1-2 days	91-159 (123)	64-161 (134)	.08-.14 (.11)	.032-.066 (.048)	6.5	2.5	5-27 (14)	0-21 (9)	.1-U (2.0)	0-12 (4.5)	0-9.5 (3)	.1-U (2.5)	29	52
3-6 days	91-166 (129)	77-163 (132)	.07-.14 (.10)	.031-.068 (.049)	5.5	3	3-24 (13)	0-17 (7)	.2-U (2.7)	.5-12 (5)	0-10 (3.5)	.1-U (2.2)	24.5	49
1-3 wks	107-182 (148)	65-161 (110)	.07-14 (.10)	.036-.080 (.053)	6	3	3-21 (11)	0-11 (4)	1.0-U (2.9)	2.5-16.5 (7.5)	0-10 (3.5)	.1-U (3.3)	21	49
1-2 mo.	121-179 (149)	31-113 (74)	.07-.13 (.10)	.033-.076 (.053)	7.5	3	3-18 (10)	0-12 (5)	.3-U (2.3)	5-21.5 (11.5)	0-6.5 (3)	.2-U (4.8)	29	53.5
3-5 mo.	106-186 (141)	7-104 (60)	.07-.15 (.11)	.032-.080 (.054)	6.5	3	3-20 (10)	0-17 (6)	.1-U (2.3)	6.5-22.5 (13)	0-10 (3)	.2-U (6.2)	32	61.5
6-11 mo.	109-169 (134)	6-99 (56)	.07-.16 (.11)	.034-.076 (.054)	8.5	3	1.5-20 (9.5)	.5-18 (4)	.1-3.9 (1.6)	6-22.5 (12.5)	0-7 (2)	.2-U (7.6)	32	53
1-2 yr.	89-151 (119)	7-101 (55)	.08-.15 (.11)	.038-.076 (.056)	6	3	2.5-17 (9)	.5-21 (8)	.05-4.3 (1.4)	6-22.5 (13)	0-6.5 (2)	.3-U (9.3)	39	49.5
3-4 yr.	73-137 (108)	6-104 (55)	.09-.16 (.12)	.041-.072 (.057)	5	3.5	1-18 (8)	.2-21 (10)	.03-2.8 (.9)	8-24.5 (15)	0-5 (1.5)	.6-U (10.8)	42	53.5
5-7 yr.	65-133 (100)	11-143 (65)	.09-.16 (.12)	.042-.079 (.059)	4	4.5	.5-14 (7)	.3-24 (12)	.02-2.0 (.7)	8.5-26.5 (16)	0-4 (1)	.9-U (11.5)	47	54
8-11 yr.	62-130 (91)	9-114 (61)	.09-.17 (.13)	.041-.085 (.062)	3	3	0-12 (5.5)	.3-25 (12)	0-1.8 (.5)	9-25.5 (16)	0-4 (1)	1.5-U (14.3)	45.5	53
12-15 yr.	60-119 (85)	11-130 (59)	.09-.18 (.14)	.044-.087 (.065)	3	3	0-10 (4)	.3-21 (11)	0-1.7 (.5)	6.5-23 (14)	0-4 (1)	1.4-U (14.7)	41	50

Oxygen Content: $CaO_2=(SaO_2)(Hgb)(1.36) + (PaO_2)(0.003)$

normal 16-22 mL O_2 / 100 mL

O_2 Extraction: A-V O_2 = (CaO_2 – $CmvO_2$) / CaO_2 (normal = 0.25)

Cardiac Output: CO = (HR)(SV) = BP/SVR = (HR)(EDV)(EF)/100

Normal CO: 0.8-1.3 L/min (infant), 1.3-3 L/min (child), 4-8 L/min (adult)

Cardiac Index = CO/BSA, Normal CI=3.5 to 5.5 L/min/m^2

Normal Stroke Volume = (~2mL x Pulse P): 5-13 mL (infant), 13-50 mL (child), 60-100 mL (adult)

FICK EQUATION

FICK: $VO_2=(CO)(C_a)-(CO)(C_v)$ therefor: $CO=VO_2/(C_a-C_v)$

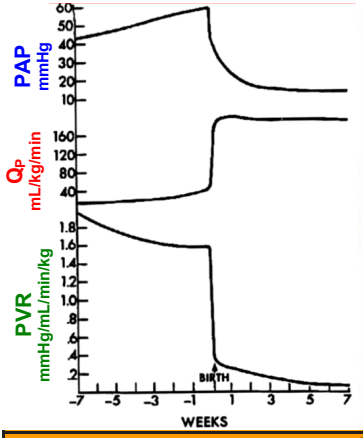
SHUNT EQUATION

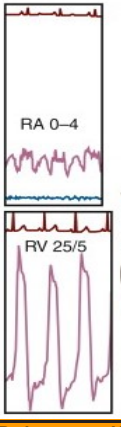
$Q_t=Q_s+Q_c$, therefor: $Q_c=Q_t-Q_S$

$Q_t(Ca_{O2})=Q_s(Cv_{O2})+(Q_t-Q_s)(Cc_{O2})$, expand to:

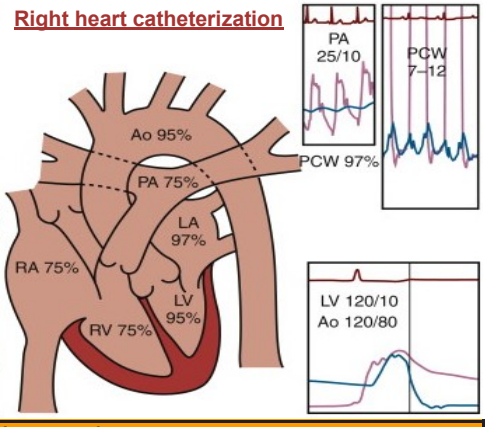
$Q_s(Cc_{O2})-Q_s(Cv_{O2})=Q_t(Cc_{O2})-Q_t(Ca_{O2})$

$Q_s/Q_t = (Cc_{O2}-Ca_{O2})/(Cc_{O2}-Cv_{O2})$





Right heart catheterization



Pulmonary Hypertension

Pulmonary HTN (PH)	mPAP>25 mmHg at sea level, >3 m/o
Pulmonary arterial HTN (PAH)	PH with PAWP< 15 mmHg and PVRI>3 WU*m^2
Idiopathic PAH	No underlying disease etiology
Pulmonary hypertensive vascular disease (PHVD)	TPG (mPAP-LAP or PAWP)> 6 mmHg

WHO Classifications
1: PAH
2: PH associated with left heart disease
3: PH due to lung disease or hypoxia
4: PAH due to chronic thromboembolic disease
5: Multifactorial or unknown cause

PH Crisis: CPR, sedation, Ventilation(↓ PaCO2, ↑ PaO2 to ↓ PVR), **100% FiO_2, $NaHCO_3$,** 40 ppm **NO, milrinone**, ECMO

Chronic PH: 1.Gentle diuresis, anticoagulation, O_2, digoxin 2.Ca^{2+} channel blocker trial, Sildenafil, endothelin receptor antagonist (bosentan, ambrisentan), PGI_2 analogues (iloprost, epoprostenol, treprostinil) Correct L→R shunt if PVRI <6WU*m^2 or PVR/SVR <0.3

Pulmonary Artery Catheter Normal Values

	Variable	Description	Adults	Child	Infant
Measured	**Cardiac Output** (L/min)	Measured by thermodilution	**4-8**	**3-6**	**1-3**
	Mixed venous O_2 saturation (%)	From pulmonary artery	**60-70**	**> 75**	**> 75**
	Pulmonary artery occlusion pressure PAOP, (mmHg)	Approximates LV filling Pressure	**4-12**	**8-11**	**6-9**
	Also measure central venous pressure (CVP), right atrial pressure (RAP), right ventricle pressure (RVP)				
Calculated	**Systemic vascular resistance** (dyn)(sec)(m-^{5})	**SVR** = (MAP-CVP)/CO	**900-1300**	**1200-3000**	**2800-4000**
	Pulmonary vascular resistance (dyn)(sec)(m-^{5})	**PVR** = (PAP-PAOP)/CO	**20-120**	**40-320**	**2000-3000**
	Cardiac index (L/min/m^2)	**CI** = CO/BSA	**2.8-4.2**	**3-4**	**2-4**
	Stroke volume index (mL/beat/m^2)	**SVI** = SV/BSA	**30-65**	**40-70**	**40-75**
	Pulmonary vascular resistance index (dyn)(sec)(cm^{-5})(m^2)	**PVRI** = [(PAP-PAOP)(80)]/CI	**250-400**	**< 200**	**< 200**
	Systemic vascular resistance index (dyn)(sec)(cm^{-5})(m^2)	**SVRI** = [(MAP-CVP)(80)]/CI	**1500-2400**	**1300-1800**	**900-1200**
	Right ventricle systolic work index (g)(m)/m^2	**RVSWI** = [1.36(PAP-CVP)(SVI)]/100	**5-10**	**5-10**	**5-11**
	Left ventricle systolic work index (g)(m)/m^2	**LVSWI** = [1.36(MAP-PAOP)(SVI)]/100	**45-60**	**30-50**	**2-40**
	Oxygen delivery index (mL/min/m^2)	**DO_2I**=(10)(CO)(CaO_2)/BSA	**450-640**	**450-700**	**450-700**
	Oxygen consumption index (mL/min/m^2)	**VO_2I**=(10)(CO)(CaO_2-CvO_2)/BSA	**85-170**	**140-190**	**150-200**
	Measures of PRELOAD, Measures of AFTERLOAD, Measures of CONTRACTILITY				

YNHH CARDIAC POST-OP ORDER SET

Admit to PICU: NPO, VS q1hr, Foley to gravity. **Vent**: **PC SIMV: V_{Te}: 8-10 ml/kg**
IVF at $^2/_3$ maintenance: D5W for > 3 m/o, D10 ½ NS for < 3 m/o
On arrival: CXR, ABG, lactate, BMP, divalents, Coags, EKG
Continue milrinone at 0.5, Dopa, Epi, Nitroprusside at bedside as needed.
1 U PRBC must be kept in-PICU fridge for any intra-cardiac lines

Overnight: CBC, Coags, ABG, Lactate, Divalents q6hrs
Goal ABG: 7.4/40 (Glenn 7.30/55), Give $NaHCO_3$ for BE < -2, Goal Hgb: >10
Antibiotics for 48hrs, GI prophylaxis, Mg > 2, K > 3.5, nl iCal
CT Output: Concerning for >3ml/kg x3hrs, >5ml/kg x1hr, or sudden change

EZ-IO	
kg	mm
< 3	15
3-39	25
> 40	45

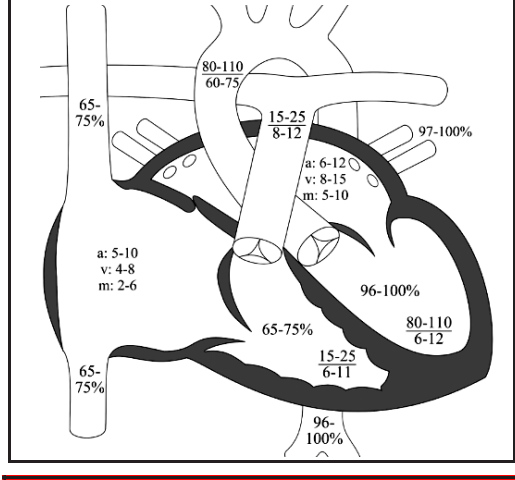
IV g	Wire
24	0.015
22	0.018
16	0.032

OVERVIEW OF CARDIAC SURGERIES

Surgery	Indication	Description	Comments
BT Shunt	Inadequate pulmonary blood flow	Subclavian to RPA or LPA gortex shunt	Palliative
Central shunt	Inadequate pulmonary blood flow	Shunt between in the ascending AO and MPA	Palliative
Damus-Kaye-Stansel	LVOT obstruction DILV, Tricuspid atresia	PA anastomosis to AO. Usually combined with a valved conduit from RV to PA to augment pulmonary blood flow	Palliative or corrective
Fontan	HLH stage 3 or any single ventricle	IVC to PA anastomosis, $^+/_-$ fenestration	Corrective Elective around 2 y/o
Glenn	HLHS stage 2	SVC to PA anastomosis	Palliative, HTN common Performed at 4-6 months
Hemi-Fontan	HLH stage 2	SVC to PA anastomosis with baffle placed in superior RA to direct IVC flow to LA (atrial lateral tunnel)	Palliative
Jatene Arterial switch	D-TGA	Transection of AO with homograft recon-struction,	Corrective Performed in first weeks
Konno	Sub-aortic stenosis	Ross with AV annular enlargement IVS incision, patch closure of surgical VSD	Corrective Long procedure
Mustard	D-TGA	Atrial switch via intra-atrial baffle. RA to LV and LA to RV	Corrective
Norwood	HLHS stage 1	PA anastomosis to AO with homograft arch construction, conduit from RSCA to MPA	Palliative Performed at birth
Rastelli	D-TGA, Any CHD with pulmonary atresia	Valved conduit from RV to PA bypassing pulmonary valve, VSD closure with LV to AO baffle	Corrective Typically long CC, BP
Ross	Aortic stenosis or insuffiency	Pulmonary autograft to AO, pulmonary homograft, CA re-implantation	Corrective
Sano	HLHS stage 1	Norwood plus RV to PA conduit instead of BT shunt	Palliative
Senning	D-TGA	Atrial switch with intra-atrial baffle	Corrective
TOF repair	TOF	Closure of VSD, resection of muscular RVOT obstruction, RVOT patch, $^+/_-$ transannular patch	Corrective
Warden	High SVC connecting APVR	Patch redirection of APVR return to LA with SVC to RA appendage	Corrective RV dysfunction common

CARDIAC SEGMENTAL ANATOMY	
Visceroarterial Situs (side of liver, right atrium and SVC)	
{S}	***Situs solitus***, right-sided morphologic right atrium, normal SVC and liver
{I}	***Situs inversus***, left-sided morphologic right atrium, SVC and liver
{A}	***Situs ambiguous***, indeterminate atrial morphology, spleen, SVC and liver
Ventricular looping (AV valves following morphologic ventricles)	
{D}	RV is anterior and to the right of the morphologic LV
{L}	RV is posterior and to the left of the morphologic LV
{X}	Ventricular morphology or anatomy is ambiguous
Great Vessel Connections	
{S}	Aorta is leftward and posterior to pulmonary artery
{I}	Inverted normally related great arteries
{D}	Aorta is anterior and to the right of the pulmonary valve
{L}	Aorta is anterior and to the left of the pulmonary valve
{X}	Position of the great vessels is ambiguous

Normal Valentine Diagram



$$Q_p : Q_s = \frac{(SaO_2 - SmvO_2)}{(SpO_2 - SpaO_2)}$$

$SpaO_2$ is equal to SaO_2 in single vent
Be sure to note $Q_{RV} = Q_p + Q_s$
Total Q_{RV} is more important
60% 0.75:1, 70%, 1:1, 90%, 3:1

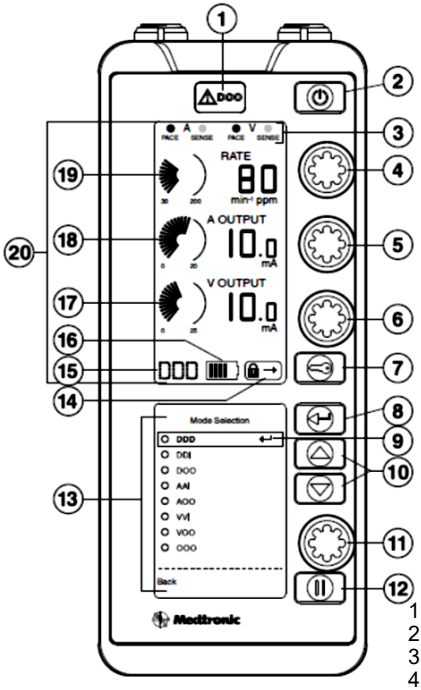
In single ventricle:

$$Q_p : Q_s = \frac{30}{(100 - SaO_2)}$$

Only true if (almost never true):
Normal A-VDO_2
No pulmonary venous desaturations

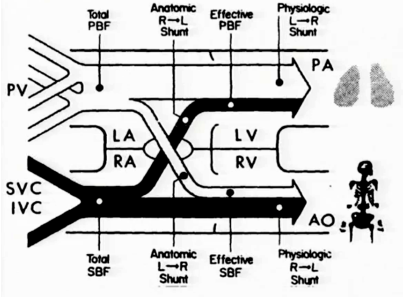
Congenital Heart Disease Physiology	
Contractile dysfunction (myocarditis)	Inotropes, judicious volume
Obstruction to systemic flow (↑LVP, ↓SV, ↓CO)	↑ CO: Prostin, inotropes, ↓ WOB, ↓ L→R shunt
Obstruction to pulm flow (R→L shunt, ↓ pulm flow), Pulm stenosis, TOF, Ebsteins, TAPVR w/obs	Prostaglandin in neonates, ↓ RVOT obstruction, ↑ SVR, β-blockers, minimize inotropes, ↓ PVR
Volume overload (L→R shunt, ↑ pulm flow)	Diuresis, inotropes, ↑ Hct, optimize Q_p:Q_s
Transposition (parallel circulations)	Assist mixing, ↑ CO, ↓ pulm edema
Single ventricle (Q_p:Q_s determined by resistances)	$SaO_2 \neq Q_p$:Q_s, Balance Q_p:Q_s by SVR, ↑ Q_p+Q_s

PACEMAKER CODES				
I: Chamber Paced	**II: Chamber Sensed**	**III: Response to sensing**	**IV: Program. rate modulation**	**V: Anti-arrhythmia functions**
O – None A – Atrium V – Ventricle D – Dual (A&V)	O – None A – Atrium V – Ventricle D – Dual (A&V)	O – None T – Triggered I – Inhibited D – Dual (A-trig, A&V inhibition)	O – None P – simple program. M – Multi program. C – Communicating	O – None P – Pacing S – Shock D – Dual (P & S)



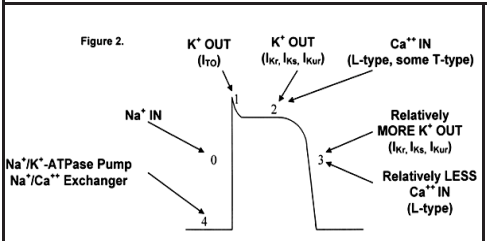
1 DOO/Emergency key
2 On/Off key
3 Pacing and sensing status bar indicators
4 Rate dial
5 A (Atrial) Output dial
6 V (Ventricular) Output dial
7 Lock/Unlock key
8 Enter key
9 Selection indicator
10 Up/Down arrow keys
11 Menu Parameter dial
12 Pause key
13 Lower screen
14 Lock indicator
15 Pacing Mode indicator
16 Battery indicator
17 V (Ventricular) Output scale
18 A (Atrial) Output scale
19 Rate scale
20 Upper screen

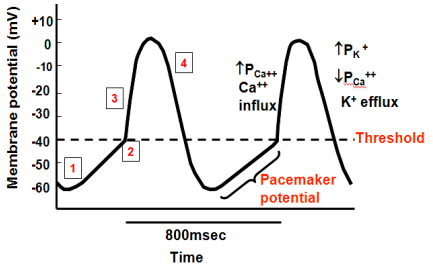
Transposition Physiology



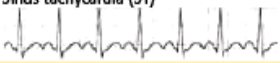
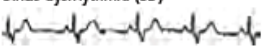
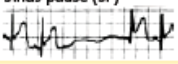
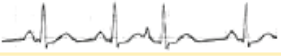
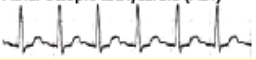
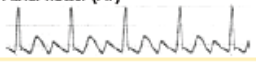
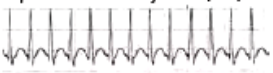
1. Turn on Pacer without connecting wires, check battery
2. Turn HR to 10 beats lower than intrinsic rate
3. Turn atrial output to lowest setting (0.1mA)
4. Turn off ventricle output, then hit arrow key to select AAI sensitivity
5. **Set Sensing: Pacemaker ability to detect intrinsic cardiac electrical activity:** Turn counterclockwise until pace flashes continuously without sensing. Turn clockwise until sensor starts to flash. Sensing threshold is that number. Sensitivity will be ½ that number
6. Now turn rate to be 10 beats above intrinsic rate
7. **Set Capture: Ability of pacemaker to excite (capture) myocardium to produce contraction:** Go back to atrial output, turn clockwise until consistent capture. (Pacing light is continuous and no sensing light). Set output 2-3x this threshold value
8. Lock pacer with these settings.

ANTI-ARRTHYMIC MEDICATIONS

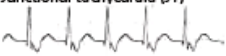
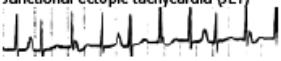
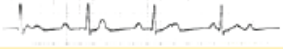
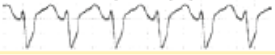
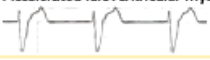




	Drug	Dose	Kinetics	Effects
Ia	**Block fast Na channels with intermediate association/dissociation. Treat VT/VF/A-fib, widen QRS**			
	Procainamide	3-6 mg/kg IV load (1g max) 0.03 ug/kg/min infusion	Peak: 1 hr t ½: 6-8 hrs	↑QRS, block fast Na channels Blood dyscrasias, rash, lupus-like
Ib	**Block fast Na channels with rapid association/dissociation. No post arrest:- risk asystole. No QRS widen**			
	Lidocaine	1 mg/kg IV load q5 min 20 ug/kg/min infusion	Peak: 1 hr t ½: 6-8hrs	Goal: 1-5 ug/mL (>6 toxic) Seizures, resp dep, hypotension
	Phenytoin	10-15 mg/kg/dose IV (1g max)	Peak: 1 hr t ½: 20 hrs	Goal: 10-25 ug/mL (>20 toxic)
Ic	**Block fast Na channels with slow association/dissociation. Used for paroxysmal A-Fib**			
	Flecainide	50-200 mg/m^2/d divided q12 Max 400 mg/day	Peak: 3 hr t ½:7-19 hr	Goal: 0.2-0.1ug/mL (>1 toxic) Neg inotrope, ↑ arrhythmia w/CHF
	Propafenone	300-400 mg/m^2/day div q6 PO 0.004 mg/kg/min IV infus.	Peak: 3 hr t ½: 3-12 hr	Worsens ventricular arrhythmias
II	↓ MI mortality. Used to treat recurrent tachyarrhythmias.			
	Propranolol	0.02 mg/kg/dose IV 2 mg/kg/day div q6 PO	Peak: 3 hr t ½: 4-6 hrs	15-150 ng/mL (0.1-1 ug/mL for VT) Caution in diabetics, asthma, CHF
	Esmolol	500 ug/kg/min for 1 min 50 ug/kg/min infusion	t ½: 9 min	Hypotension, emesis
III	**Block K channel, although agents have cross-reactivity. Used to treat WPW, VT/VF, A-Fib, A-Flut**			
	Ibutalide	0.001 mg/kg over 10min Max: 2 mg (over 60kg)	t ½: 2-12hrs	VT or TdeP in 10%, ECG monitoring Do not give with class I or III agents
	Sotalol	2-8 mg/kg/day divided q12hr	t ½: 12 hrs	↑ QTc, Do not give with class Ia agents Assure normal Mg, K (¯ risk TdeP)
	Amiodarone	1 mg/kg IV load over 20 min 10 mg/kg/day infusion w/D5	Effect: 3hrs t ½: 30 d	Goal: > 1 ug/mL (>2.5 ug/mL toxic) ↓ HR, ↓ BP, ↓ thyroid, pulm fibrosis
IV	**Block slow Ca channels. Used to treat SVT and slow ventricular rate in atrial tachycardias.**			
	Verapamil	0.1-0.3 mg/kg IV (max 10mg) 4-17 mg/kg div q8hr PO	t ½: 6-12hr	Goal: 0.1 to 0.3 ug/mL Do not use in < 3 months, hypotension
	Diltiazem	0.25 mg/kg IV over 2 hrs 0.125 mg/kg/hr IV infusion 1.5 mg/kg/day divided TID	Peak: 5 min t ½: 3-4 hrs	Do not use in < 3 months, hypotension
V	**Bretylium**	5-10 mg IVP (resistant VF) 15-30 ug/kg/min IV infusion	Peak: 1 hr t ½: 6-12hrs	↑Levels in renal failure Hypotension with IV bolus
	Digoxin	20 ug/kg IV q24hr 30 ug/kg PO q24hr	t ½: 18-48hr	Goal: 0.5-2 ng/mL (>3.5 OK) ↑ PVCs, VT
	Adenosine	50-100 ug/kg IVP Up to 400 ug/kg	t ½: 10 sec	Use in SVT, AVRT, AVNRT Weak bronchoconstrictor,
	Phenylephrin	20-100 ug/kg IVP (Tet spell) 0.1-0.5 ug/kg/min IV infusion	Peak: 1 min t ½: 20 min	↑ myocardial VO_2

Rhythm	Characteristics
Normal sinus rhythm (NSR) 	Regular rhythm with HR normal for age; A:V conduction 1:1
Sinus bradycardia (SB) 	Regular rhythm with HR <5th percentile for age; A:V conduction 1:1
Sinus tachycardia (ST) 	Regular rhythm with HR >95th percentile for age; A:V conduction 1:1
Sinus dysrhythmia (SD) 	Rhythm irregular with normal HR; AV conduction 1:1; common with variable respirations
Sinus pause (SP) 	Seen in digitalis toxicity or hypercalcemia
Sick-sinus-syndrome (SSS) 	Rapid atrial rhythm interspersed with sinus bradycardia; aka sinus nodal dysfunction (SND)
Premature atrial contraction (PAC) 	Early atrial contraction with abnormal p-wave, shortened P-R interval and narrow QRS
Wolf Parkinson White (WPW) 	Antegrade anomalous AV conduction via accessory pathway. Short PR interval, QRS morphology abnormal. Potential for variable dysrhythmias, most common in AV re-entry tachycardias.
Atrial ectopic tachycardia (AET) 	Variant of SVT; rapid atrial rate with narrow QRS; HR 120-300; non-responsive to cardioversion; can lead to tachycardic induced cardiomyopathy
Atrial fibrillation (A fib) 	Irregular rhythm; atrial rate 350-600 without discreet p-waves; ventricular response 110-150; normal QRS
Atrial flutter (AF) 	Atrial rate 250-350 regular with variable ventricular rate; sawtooth pattern; normal QRS
Supraventricular tachycardia (SVT) 	Re-entrant tachycardia originating other than SA node above the AV node; HR >230 bpm; abnormal p-wave with narrow QRS; responds to vagal maneuvers, adenosine and/or cardioversion
Premature junctional contraction (PJC) 	Premature beat originating near AV node; inverted or absent p-wave

ALCAPA: Deep q-waves, >3 mm depth, >30 ms wide in I, aVL, V6
QR in I, aVL and V5-V7, ST elevation in inferior and lateral leads

Rhythm	Characteristics
Junctional rhythm (JR) 	Slower heart rate with origin above or at AV node; absent or inverted p-waves
Junctional tachycardia (JT) 	Heart rate faster than junctional rhythm with origin above or at AV node; absent or inverted p-waves
Junctional ectopic tachycardia (JET) 	Abnormal automaticity focus near or above AV node; rapid heart rate with narrow QRS; seen post-op congenital cardiac repair, as congenital dysrhythmia or digoxin toxicity; does not respond to cardioversion or adenosine
1° block 	Prolonged P-R interval for age; 1:1 conduction; can progress into advanced blocks
2° AV block Mobitz I or Wenkebach 	P-R interval increases until QRS complex dropped; atrial conduction > ventricular; irregular rhythm
2° AV block Mobitz II 	Non-conducted p-waves seen, P-R interval constant; atrial conduction > ventricular; regular atrial rate with ventricular rate regular or irregular
3° AV block (AV dissociation) 	No relationship (conduction) between atria (p wave) and ventricle (QRS); atrial conduction > ventricular; atrial and ventricular rates independently regular
Premature ventricular complex (PVC) 	Premature ventricular depolarization; unifocal or multifocal; couplets consists of 2 pvcs combined; can occur with regular frequency i.e. bigeminal or trigeminal
Ventricular tachycardia (VT) 	3 or more PVCs with widened QRS; absent p-wave. With or without pulse
Ventricular fibrillation (VF) 	Asynchronous depolarization of ventricles with abnormal size and shape of QRS pulseless
Torsade de pointes (TDP) 	Polymorphous VT variant with axis change direction and variable ventricular rate; prolonged QTc; common in hypomagnesia
Accelerated idioventricular rhythm (AIVR) 	3 or more ectopic ventricular beats with rate slower than seen in VT; seen in digoxin toxicity, electrolyte imbalance, myocardial infarction (MI) and hypoxemia
Pulseless electromechanical activity (PEA) 	AKA electromechanical dissociation (EMD); normal ECG without pulse. Causes: hypothermia, hyperkalemia, hypoxemia, hypovolemia, hypoglycemia, acidosis, tension pneumothorax, pericardial tamponade, toxins, thrombosis (pulmonary or coronary), trauma
Asystole 	Absence of myocardial electrical activity; no ECG complexes present

RBBB: Wide QRS, V1: rSR", V6: qRS

EXTRACORPOREAL MEMBRANE OXYGENATION

Inclusion: OI > 40, A-a >450 mmHg, P/F >45, Acute deterioration of reversible process
Exclusion: Hemorrhage, coagulopathy, low QOL, irreversible terminal disease

ECMO SITE	ADVANTAGES	DISADVANTAGES
V-A Veno-arterial	Full support, higher O2, Decrease pulm art pressure, Venous sat, 40-50% bypass	Ligate carotid artery Arterial debris
V-V Veno-Veno	Pulsatile flow, avoid carotid artery occlusion, perfusion of lungs, perfusion of coronaries, easier cannulation, 50-60% bypass	No cardiac support No mixed venous SaO2

ECMO TROUBLESHOOTING

Increase oxygenation	Increase FiO2 to oxygenator, consider re-circulation if on VV
Increase ventilation	Increase sweep gas flow rate or decrease % CO2 in sweep gas
Increased (-) pressure	Give volume, treat pneumothorax, tamponade
Declining SvO2	Increase ECMO flow by 10%

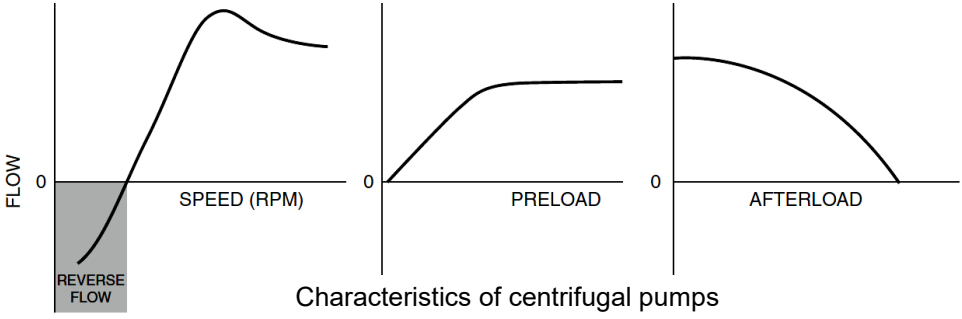
YNHH PRE-ECMO CHECKLIST

Patient meets inclusion criteria, consents signed, ECMO blood products ordered in EPIC
Notify: PICU, Pedi Surg, Perfusion (688-2360 or 688-4841), Blood bank (688-2443) Pharm (688-7982)
Meds: **Epi, Vec, Fentanyl** (25 mcg/kg), **Versed, Atropine, $CaCl_2$** (10 mg/kg), **5% Albumin, $NaHCO_3$**
Infusions: **Nipride** (0.5 mcg/kg/min), **Dopa** (5 mcg/kg/min), **Heparin** (25 U/kg/hr = 1 mL/hr, ACT 300)
Heparin Concentration: 25Units x weight in kg x 50 mL for a 50mL syringe at 1 ml/hr
X-ray plate placed under patient, De-fib pads in place, IV access, ETT taped, PulseOx on foot, no heparin

CANNULATION CHECKLIST

Circuit primed by perfusionist to match patient.
pRBC 2 to 3 units, **FFP** 0 to 1 unit, **Cyro** 2 to 3 units, **Platelets** 2 to 3 units
Fentanyl 25 mg/kg, **Vecuronium** 0.1 mg/kg, **Heparin 100U/kg (4 mL)** when vessels isolated
ACT q5 min, bolus to goal of >300, Heparin infusion at 25 U/kg/hr (1 mL/hr) once ACT<300

Recommended "Full Flow"		Recommended Circuit	
< 7 kg	**200 mL/kg/min**	**< 10 kg**	**1/4 inch**
7 to 10 kg	**150 mL/kg/min**	**10 t0 15 kg**	**1/4 or 3/8**
10 to 20 kg	**120 mL/kg/min**	**> 15 kg**	**3/8 inch**
20 to 25 kg	**100 mL/kg/min**	Goal Hct: VA:40, VV:45; Plt>150, Act: 180-200 Fibrinogen > 150	
> 25 kg	**80 mL/kg/min**		



Characteristics of centrifugal pumps

ECMO TROUBLESHOOTING by Nick Mark MD & Jonah Rubin MD

CIRCUIT PROBLEMS

CANNULA DISPLACEMENT compromises the circuit and can cause an air embolism, major bleed, and reduced blood flows. Follow **ECMO emergency protocol** ⚠ and consider massive transfusion.

CIRCUIT THROMBOSIS: Clots in the tubing can increase flow resistance. Clots in oxygenator may also impair gas exchange. Acutely or over time, this may lead to **OXYGENATOR FAILURE.** Anticoagulation may prevent clot formation.

CHATTER is visible shaking of the tubing from variable venous drainage when the pump is trying to drain more than what native venous return allows. Pump may repeatedly start/stop causing **CUT OUTS. Options**: Reduce RPM, administer fluids, assess cannula positioning

AIR EMBOLISM can cause immediate pump, oxygenator, or circuit failure. Follow **ECMO emergency protocol** ⚠ and place head down. Locate source to prevent further entrainment. If venous source, may place in left lateral position and aspirate from drainage cannula

50cc syringes can be used to remove air from the circuit

Clamps are used emergently to stop blood flow

PUMP PROBLEMS

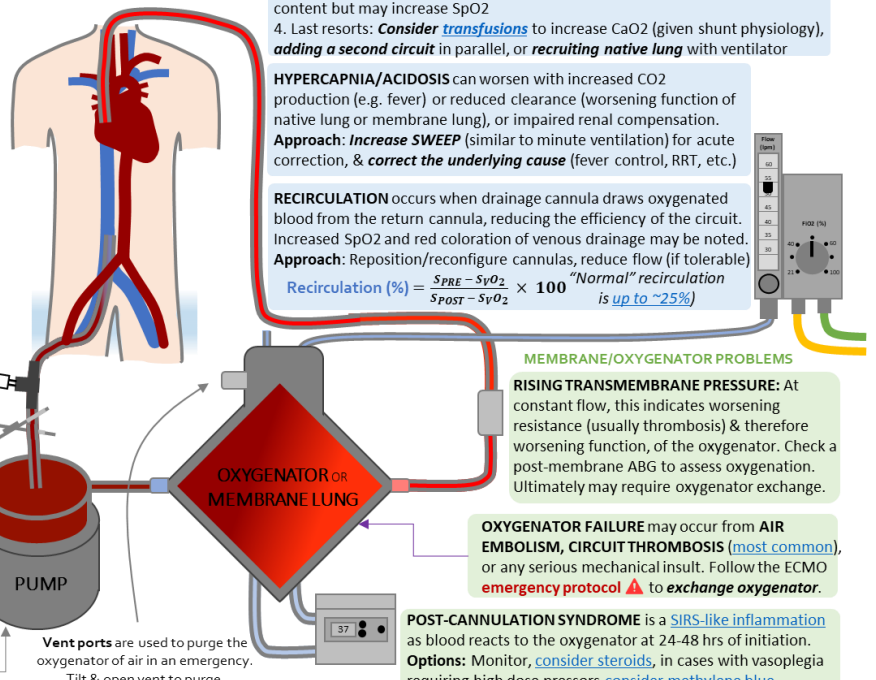
INADEQUATE FLOW can occur from kinking, cannula malposition, decreased venous return (± **CHATTER**), and **CIRCUIT THROMBOSIS** (same RPM yielding less LPM flow).
Approach: ***Treat the cause***! Some patients, especially with high BMI, may need an extra venous drainage cannula to achieve goal flow.

PUMP FAILURE may occur from **CIRCUIT THROMBOSIS, AIR EMBOLISM,** or other insult. Follow **emergency protocol** ⚠. A backup pump should be readily available. With some ECMO products, a mechanical crank can be used temporarily until a new pump is available.

ECMO EMERGENCY PROTOCOL ⚠

Team should train/practice &
have necessary supplies at bedside

- Clamp drainage & return lines
- Call for help
- Return to pre-ECMO vent settings
- Exchange of oxygenator or entire circuit may be needed



Vent ports are used to purge the oxygenator of air in an emergency. Tilt & open vent to purge.

GAS EXCHANGE PROBLEMS

HYPOXEMIA is common as oxygenated blood always mixes with deoxygenated native circulation, although this may not reflect insufficient oxygen delivery. A low SpO2 may be tolerable, however SpO2 < 85% may be critical.
Options:
1. ***Increase flow*** – may be limited by **CHATTER,** diminishing returns if flow >7LPM
2. ***Increase*** F_DO_2 – diminishing returns when post-oxygenator SpO2 is ~100%
3. ***Reduce native cardiac output*** (e.g. beta-blocker) – does not change oxygen content but may increase SpO2
4. Last resorts: ***Consider*** ***transfusions*** to increase CaO2 (given shunt physiology), ***adding a second circuit*** in parallel, or ***recruiting native lung*** with ventilator

HYPERCAPNIA/ACIDOSIS can worsen with increased CO2 production (e.g. fever) or reduced clearance (worsening function of native lung or membrane lung), or impaired renal compensation.
Approach: ***Increase SWEEP*** (similar to minute ventilation) for acute correction, & ***correct the underlying cause*** (fever control, RRT, etc.)

RECIRCULATION occurs when drainage cannula draws oxygenated blood from the return cannula, reducing the efficiency of the circuit. Increased SpO2 and red coloration of venous drainage may be noted.
Approach: Reposition/reconfigure cannulas, reduce flow (if tolerable)

Recirculation (%) $= \frac{S_{PRE} - S_VO_2}{S_{POST} - S_VO_2} \times 100$ *"Normal" recirculation is up to ~25%*

MEMBRANE/OXYGENATOR PROBLEMS

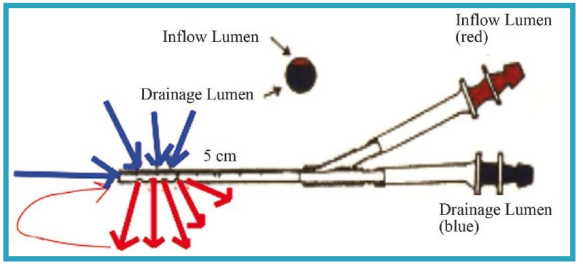
RISING TRANSMEMBRANE PRESSURE: At constant flow, this indicates worsening resistance (usually thrombosis) & therefore worsening function, of the oxygenator. Check a post-membrane ABG to assess oxygenation. Ultimately may require oxygenator exchange.

OXYGENATOR FAILURE may occur from **AIR EMBOLISM, CIRCUIT THROMBOSIS** (most common), or any serious mechanical insult. Follow the ECMO **emergency protocol** ⚠ to ***exchange oxygenator***.

POST-CANNULATION SYNDROME is a SIRS-like inflammation as blood reacts to the oxygenator at 24-48 hrs of initiation.
Options: Monitor, consider steroids, in cases with vasoplegia requiring high dose pressors consider methylene blue

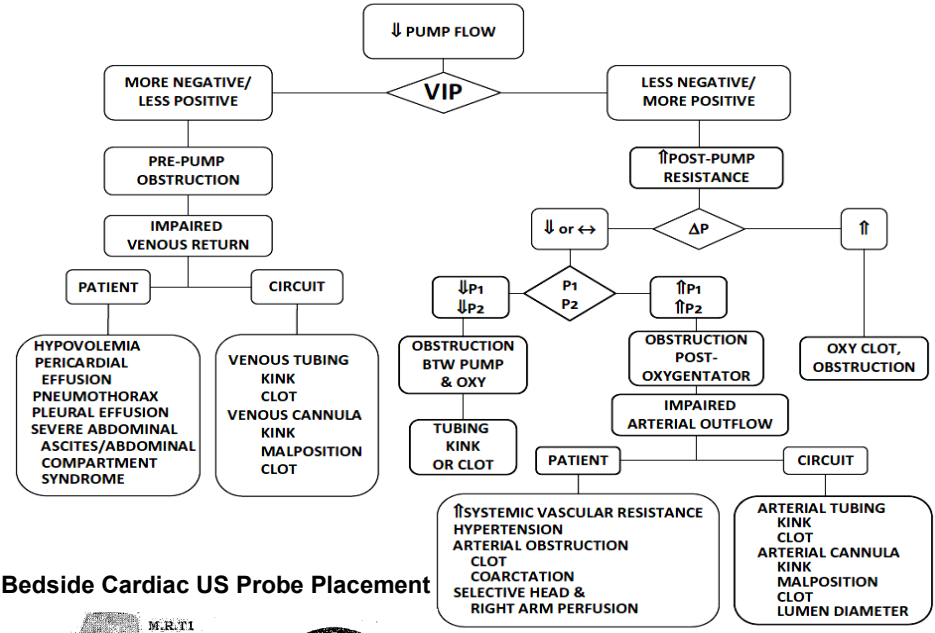
ECMO Trouble-shooting algorithms

- ↓MAP
  - ↓CVP
    - ↓PUMP FLOW
      - PT
        - Hypovolemia
        - Hemorrhage
      - CIRCUIT
        - Excessive fluid removal
    - ↑RotaFLOW
      - PT
        - Venodilation
        - ↓SVR
      - CIRCUIT
        - ↑Bridge flow
        - Cannula dislodged
  - ↔CVP
    - ↑RotaFLOW
      - PT
        - ↓Fxn
        - ↓SVR
      - CIRCUIT
        - ↑Bridge flow
  - ↑CVP
    - ↓RotaFLOW
      - PT
        - Pneumothorax
        - Lg pleural effusion
        - Tamponade
        - ↓Cardiac function
        - Arterial obstruction
        - Arterial clot
        - Coarctation
      - CIRCUIT
        - VENOUS LIMB—cannula
          - Too small
          - Malposition
          - Occlusion/clot
          - Kink
        - CIRCUIT MALFUNCTION
          - Tubing obstruction/clot
          - Ø Rotaflow spin
          - Oxygenator inflow obx
          - Oxygenator clotting
          - Oxygenator outflow obx
          - Bubble detected
        - ARTERIAL LIMB--cannula
          - Malposition
          - Occlusion/clot
          - Kink
          - Too small

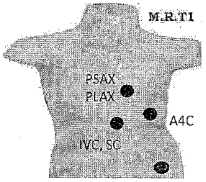


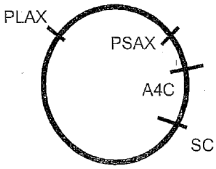
- ↑MAP
  - ↓CVP
    - ↓RotaFLOW
      - PT
        - ↑cardiac fxn
        - ↑ SVR
      - CIRCUIT
        - Excessive RPMs/ flow
    - ↑RotaFLOW
  - ↔CVP
    - ↓RotaFLOW
      - PT
        - ↑cardiac fxn
        - ↑ SVR
      - CIRCUIT
        - Excessive RPMs/ flow
    - ↑RotaFLOW
  - ↑CVP
    - ↓RotaFLOW
      - PT
        - ↑ SVR

ECMO Trouble-shooting algorithms

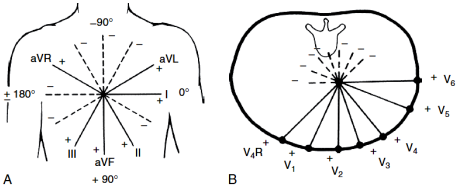


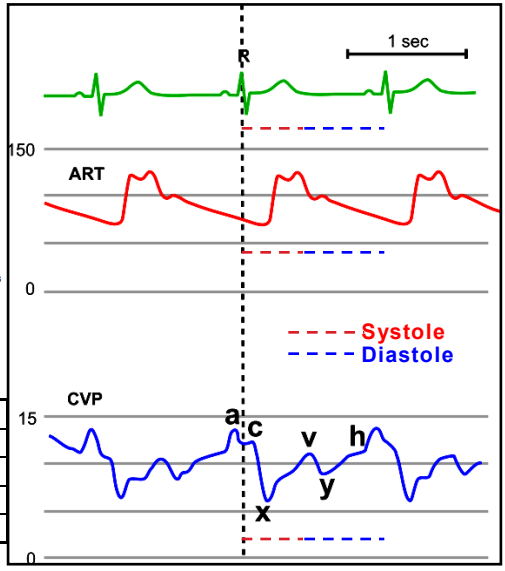
Bedside Cardiac US Probe Placement





EKG Lead Placement

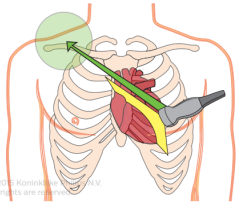


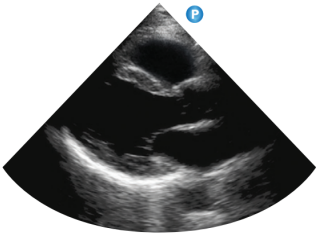


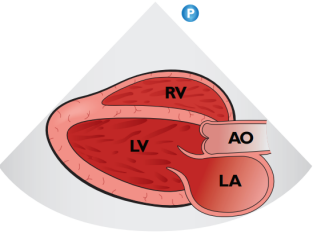
***a* wave**	Atrial contraction
***c* wave**	Tricuspid valve bulging
***v* wave**	Systolic filling of the atrium
***x* descent**	Atrial relaxation
***y* descent**	Early ventricular filling

Critical Care Bedside Cardiac Ultrasound Windows

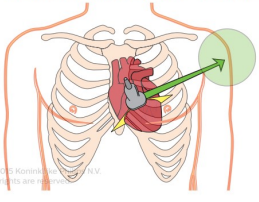
Parasternal long-axis

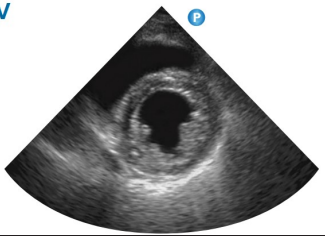


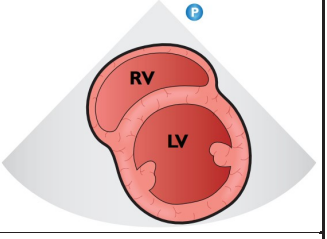




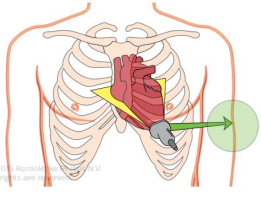
Parasternal short-axis LV

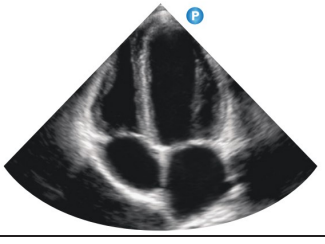


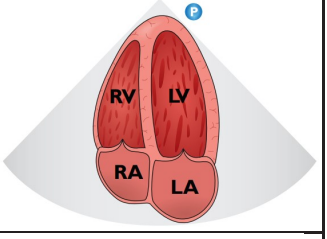




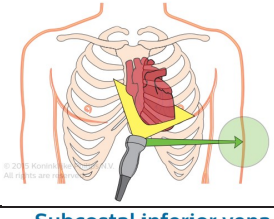
Apical four-chamber

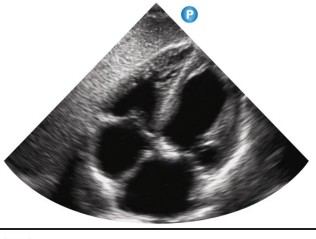


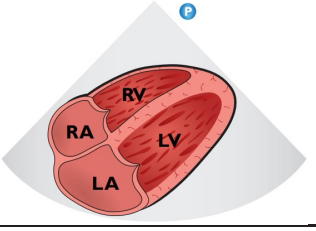




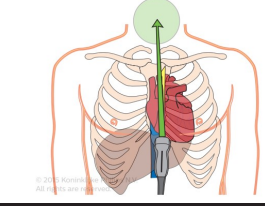
Subcostal four-chamber

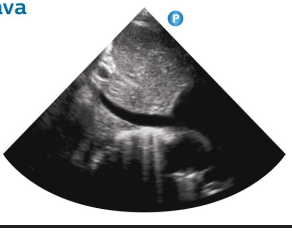


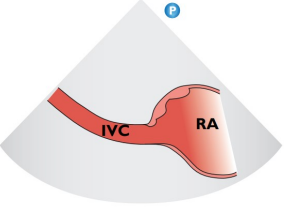




Subcostal inferior vena cava







SEDATION

	Minimal	Moderate	Deep	Anesthesia
Responsiveness	Normal to verbal	Purposeful to verbal or tactile	Purposeful to painful tactile	Un-arousable
Airway	Unaffected	Minimally affected	Intervention may be required	Intervention required
Ventilation	Unaffected	Adequate	May be inadequate	Intervention required
CV status	Unaffected	Usually maintained	Usually maintained	My be impaired

ANESTHESIA REVERSAL

Opiates	**Naloxone IV/IO/IM/SC/ETT**: Partial: 0.001 mg/kg Full: 0.1 mg/kg (max 2 mg) q 2min (cumulative max 10 mg) then infusion 0.002-0.2 mg/kg/hr
Benzodiazepines	**Flumazenil IV:** 0.01 mg/kg IV (max 0.2 mg) q1 min
Non-depolarizing neuromuscular blockers	**Neostigmine** IV: 0.03-0.07 mg/kg (max 5 mg) and **Glycopyrrolate** IV: 0.01 mg/kg *OR* **Edrophonium** IV: 0.5-1 mg/kg and **Atropine** IV: 0.02 mg/kg **Sugammadex** IV: 2 to 16 mg/kg (asystole)

PCA/NCA DOSING GUIDELINES

Medication	Load Dose (mcg/kg)	PCA Bolus (mcg/kg)	PCA Basal (mcg/kg/hr)	4-hr Max (mg/kg)
Morphine	**30 - 50**	**15 - 20**	**15 - 20**	**0.8 - 1.2**
Hydromorphone	**6 - 10**	**3 - 4**	**3 - 4**	**24 - 56**
Fentanyl	**0.5 - 1**	**0.25 - 0.5**	**0.5 - 1**	**4**
Methadone	**75 - 100**	**10 - 20**	**10 - 20**	
Ketamine	**0.05**		**0.05 - 1.2**	

PCA/NCA SIDE EFFECT MANAGEMENT

Nausea & vomiting	**Ondansetron**	0.1-0.15 mg/kg/dose	IV/PO q6hr	First line
	Reglan	0.1 mg/kg/dose	IV q6hr	
Pruritus	**Nalaxone**	0.05-1.5 ug/kg/hr	IV infusion	First line
	Benadryl	0.5 mg/kg/dose	IV/PO q6hr	
	Nalbuphine	0.05 mg/kg/dose	IV q6hr	
Sedation	Tolerance typically develops, if significant reduce PCA dose			
Resp Depression	Hold Opioids for RR<8; **Naloxone:** 0.001-0.003 mg/kg/dose			
Constipation	Tolerance does not develop. Prophylaxis with **miralax/colace**			

Pediatric ICU Delirium

CAPD
RASS Score:
(4=Never, 0=Always)
1. Eye contact?
2. Purposeful actions
3. Aware of surroundings
4. Communicate needs
(0=Never, 4=Always)
5. Restless
6. Inconsolable
7. Underactive
8. Long response time

Delirium: Disturbance of consciousness and cognition
RN Screen with CAPD twice daily, higher is worse
Low is 0, high is low 30s
CAPD < 9 is Negative, continue to monitor BID
CAPD ≥ 9 is Positive: Establish day/night (cluster care, sleep hygiene, close door, limit light/noise), Re-orient patient, Promote familiar environment (toys, pictures, same caregivers), Minimize restraints, Review tubes/lines, Mobilize, PT/OT/Child life. Decrease benzodiazepine use.
Consider Psychiatry consult.
Consider pharmacotherapy if initial interventions fail

Melatonin PO: 0.5-5 mg before bedtime
Zolpidem PO: 0.25 mg/kg (max 10 mg) at bedtime
Haldol IV/IM: Acute agitation: 0.05-0.15 mg/kg (max 5 mg) q1hr
Quetiapine PO: **Preferred agent**: >10y/o Titrate up: 25 mg q12 to 200 mg q8 (*CYP3A4*)
Risperidone PO: Infants: 0.05-0.1 mg, <5y/o: 0.1-0.2 mg, >5y/o: 0.2-6 mg/day

RASS Score (Extubated)

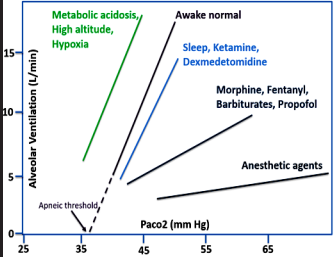
+4		Combative, immediate danger
+3		Very Agitated, aggressive
+2		Agitated, non-purposeful movement
+1		Restless, non-aggressive
0		Alert, calm
-1	Verbal Stim	Drowsy but awakens
-2	Verbal Stim	Light sedation, briefly awake
-3	Verbal Stim	Moderate sedation
-4	Physical Stim	Deep sedation, opens eyes
-5	Physical Stim	Obtunded, no response

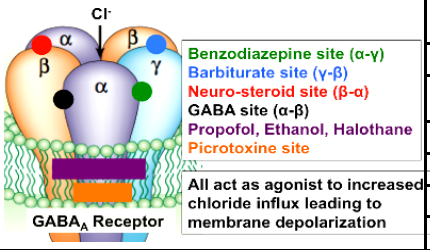
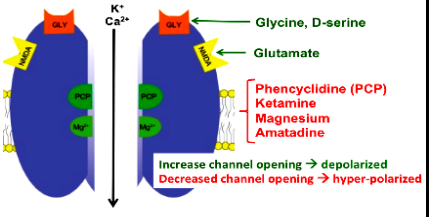
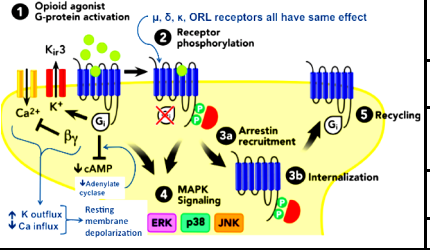
SBS Score (Intubated)

-3	Unresponsive
-2	Responds to noxious stimulation
-1	Responsive to touch/voice
0	Awake and able to calm
+1	Restless and difficult to calm
+2	Agitated

Train of 4 (Paralyzed)

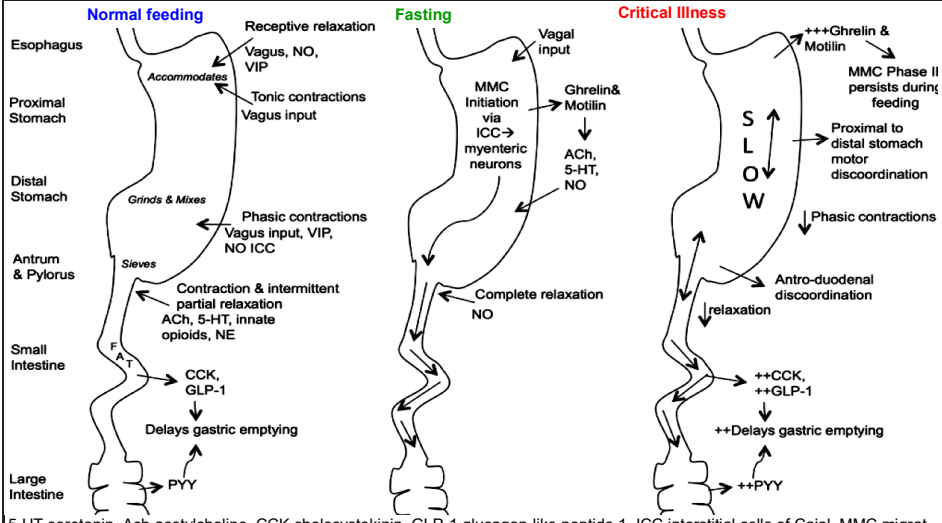
Twitch	% Ach$_R$ blocked	Interpretation
0	**100**	Over-paralyzed Noxious procedures
1	**90**	Adequate NMBA for intubation/procedures
2	**80**	
3	**70**	Borderline NMBA
4	**0-70**	Inadequate NMBA



Mechanism	Drug	Peak / Dur IV	MS	HR	BP	Resp	Other
	**Diazepam**	**5 min/8 hr**	↓	-	-	-	Skeletal muscle relaxant, P450, active metabolites ↓ airway tone
	Lorazepam	**15 min/6 hrs**	↓	-	-	-	
	Midazolam	**5 /60 min**	↓	-	-	-	
	Pentobarbital	**5 /20 min**	↓↓	↓	↓↓	↓	Rarely used in PICU
	Thiopental	**1 /30 min**	↓↓	↓	↓↓	↓	
	Propofol	**1 /10 min**	↓↓	↓	↓↓	↓↓	Soy/Egg allergens
	Etomidate	**1 /5 min**	↓↓	-	-	-	11-βOH blocker
	**Ketamine**	**5 min / 1-2 hours**	↓	↑	↑	↔	Emergence reaction **Increased Secretions lead to** laryngospasm May pre-treat with :Atropine OR Glycopyrrolate
Bind central presynaptic α_2 receptors that ↓ presynaptic norepi → ↓ sympath outflow	**Precedex**	**1 /15 min**	↓	-	-	-	↓HR, BP at ↑ doses Do not use in heart block
Blocks central D2, α_1 > D1 > $5HT_2$, H1 receptors → ↓ cAMP, IP3, Ca^{2+} influx	**Haloperidol**	**30 min/4 hrs**	↓	↓	-	-	Qtc, ↑ EPS
Blocks central H1 > M1 > D2 receptors	**Benadryl**	**5 min/ 4 hrs**	↓	-	-	-	Paradoxical reaction
	**Morphine**	**5 min/4 hr**	↓↓	-	↓	↓	Histamine release
	Fentanyl	**5 min/ 1-2hr**	↓	-	-	-	Rigid chest with rapid IVP
	Hydromorphine	**20 min/5hr**	↓	-	-	↓	
	Oxycodone	**20 min/4 hr**	↓	-	-	-	
	Methadone	**2hr/20hr**	↓	-	↓	↓	↑QTc
COX 1/2 inhibitor → ↓ prostaglandins	**Ketorolac**	**2hr/6hrs**	-	-	-	-	BUN/Cr, GI

FEN / GI

GI Motility in Critical Illness



5-HT serotonin, Ach acetylcholine, CCK cholecystokinin, GLP-1 glucagon-like peptide 1, ICC interstitial cells of Cajal, MMC migrating motor complex, NE norepinephrine, NO nitric oxide, PYY peptide-YY, VIP vasoactive intestinal polypeptide

Yale Enteral Nutrition Protocol

Indications: Insufficient caloric intake by mouth, mechanical ventilation, >10% admit wt loss
Contraindications: Post-cardiac/abdominal surgery, Epi/Norepi > 0.1 mcg/kg/hr, Dopa > 10 mcg/kg/hr
Begin NG feeds at 1 mg/kg/hr (max 25 mL/hr), For all patients, start ***docusate sodium*** (5 mg/kg/day q12, max 100mg) and ***polyethylene glycol 3350*** ($^1/_2$ [<15kg] to 1 [>15 kg] packet) daily
Advance by 1 mL/kg/hr q4 hrs until goal reached of intolerance develops
Intolerance: Gastric residuals > 4hrs of feed, ↑ abdominal girth x2, Emesis x2, Diarrhea x3

Diagnose dysmotility: Tylenol absorption test (absorbed in small int.), stomach U/S, UGI
If no stool in 48hrs start **metoclopramide** NG 0.1 mg/kg/dose q6 (max 10 mg, D_2 antagonist), **milk & molasses enema with lactulose** (20mL NGq12hr). **Erythromycin** PO, 10 mg/kg or IV 2-5 mg/kg/dose q6 (motilin agonist), **Cyproheptadine** NG 0.08 mg/kg/dose q8 (5HT agonist). **Methylnaltrexone** for opioid-induced constipation

Formula: ***0-12 month:*** Breastmilk or infant formula. ***1-13 years (>40 kg):*** Pediasure, Peptamin Jr/ Pediasure peptide (hydrolyzed) Neocate/Elecare (elemental)/ ***>13 year (>40kg):*** Osmolite 1cal/mL or Jevity 1.2 cal/mL. ***Goals:*** 0-1: 80 $^{cal}/_d$, 1-3: 70 $^{cal}/_d$, 4-6: 65 $^{cal}/_d$, 7-9: 55 $^{cal}/_d$, 10-12: 45 $^{cal}/_d$, 13-16: 35 $^{cal}/_d$

Intra-Abdominal Hypertension (IAH) & Abdominal Compartment Syndrome (ACS)

IAH: Intra-abdominal pressure (*bladder pressure*) ≥ 12 mmHg (*1 mL/kg or 30 mL into bladder)*
ACS: IAH with new organ failures (no UOP, ↑ Peak vent pressures, ↓ preload with IVC collapse)

IAP ≥ 20 mmHg warrants investigation: Bladder pressure q4, abd girth, BUN/Cr, Lac, Abd U/S
↓ **Abd Wall C:** Sedation, analgesia, paralysis, HOB ≤ 30˚
↓ **Abd lumenal Vol:** NG/rectal tube to LCWS, prokinetic agents, enemas
Optimize fluid resuscitation: Hyptertonic fluids, colloids, vasopressors, diuresis, CVVH
Goals: **CVP_{TM}** = CVP - $^{IAP}/_2$, **$PAOP_{TM}$** = PAOP - $^{IAP}/_2$, **$Pplat_{TM}$** = Pplat - $^{IAP}/_2$
↓ **Extra-lumenal Vol:** Abd U/S or CT, pericentesis, surgery C/S to open abdomen

ELECTROLYTE CORRECTIONS

	Treatment	Work-Up
↑ Ca	**Loop diuretics**, IVF at 2-3xM, **Bisphosphonates** with or without **calcitonin**	CMP, PO_4, MG, PTH, VitD, Urine Ca/Cr/ PO_4, EKG
↓ Ca	$CaCl_2$ 20 mg/kg q10 min (max 1 g/dose) *OR* **CaGluconate** 100 mg/kg q10 min (max 2 g/dose) **$MgSO_4$** 25-50 mg/kg max 2.5 g/dose	CMP, PO_4, MG, PTH, VitD, Urine Ca/Cr/ PO_4/protein, EKG iCa, Left wrist X-ray
↑ Na	NS bolus to correct dehydration Correct Free water deficit (FWD) over 24-48 hrs Goal ↓ in Na10-15 mEq/L per 24hr **Vasopressin**: 0.5 microUnits/kg/hr, titrate q15min to goal UOP of <1-2 mL/kg/hr.	4 mL FW/kg = ↓ Na 1 mEq/L FWD=0.6(wt)({[Na]/140} - 1)
↓ Na	Slow correction: 0.5 mEq/L/hr or 15 mEq/L/day Symptomatic: 3% saline: 3-6 mL/kg (5 will ↑Na by 5mEq/L) Na in mEq = $(Na_{goal}-Na_{meas})(Wt)(1.2)$	Urine & serum osm UA, urine lytes, CMP, lipids H_2O restriction if SIADH
↑ K	**Dextrose** 1-2 g/kg IV with Insulin 0.1 U/kg IV $CaCl_2$ 10 -20 mg/kg IV, **Albuterol**, **$NaHCO_3$** 1-2 mEq/kg **Kayexalate:** 1-2g/kg/dose NG/PR, **Lasix,** Dialysis	CMP, ABG, CK, UA, EKG Urine lytes
↓ K	0.5-1 mEq/kg (max 40 mEq) **KCl** IV over 1-2 hours	Urine K > 40 $^{meq}/_{L}$ → renal wasting Urine $^{K}/_{Cr}$ > 15 → renal wasting
↓ Glu	**D10:** 5 mL/kg PIV, D25: 2 mL/kg or D50: 1 mL/kg CVL Infusion: 6-8 mg/kg/min of D10 No IV: **Glucagon** 0.003, **Epinephrine** 0.01 mg/kg IM/SQ If >10 mg/kg/min: **Diazoxide** 3-8 mg/kg/day q12 *OR* **Octreotide** 10 mcg/kg IV or SQ q8hr	Critical labs: insulin, C-peptide, cortisol, GH, FFA, lactate, acetone, LFTs, NH_4, U Glu, urine ketones, IGF-1
↓ Mg	25-50 mg/kg **$MgSO_4$** over 2-4 hours	FE_{Mg} < 2% → non renal loss 24hr urine Mg > 30 mg→renal loss
↓ PO_4	0.15-0.3 mmol/kg of **NaPhos**/**KPhos** IV over 4hr	24hr Urine PO_4 excretion
↑ NH_4^+	**NaBenzoate** IV: <20kg: 250mg/kg load over 2hrs then 250mg/kg/day, >20kg 5.5g/m^2 load and infusion **Arginine** IV: 200 mg/kg load over 2 hrs then 200 mg/kg/day infusion	
↓ pH (Metabolic)	**$NaCHO_3$ IV:** 0.5-2 mEq/kg slow bolus [(Base deficit)(wt)(0.3) = dose, (max 50 mEq = 1 Amp) **Tromethamine (THAM) IV:** Dose in mL =(Base deficit)(wt)x1.1. Infuse 1-2 mL/hr. If base deficit is unknown give 1-2 mEg/kg (max 15 mEq/kg/day). Support ventilation, treat cause, consider dialysis	

DIFFERENTIAL DIAGNOSIS FOR METABOLIC DISEASE

http://newenglandconsortium.org/for-professionals/acute-illness-protocols/

	Amino Acid	Urea Cycle	Carbohydrate Metabolism	Fatty Acid	Organic Acid	Energy Metabolism
Example	MSUD	OTC def.	Glycogen storage def.	MCAD def.	Methylmol acidemia	Pyruvate dehydro def.
Blood pH	NL or ↓	↑ (respiratory)	NL or ↓	Variable	↓ (metabolic)	NL or ↓
Anion Gap	↑	Normal	↑	Variable	↑	↑
Ketones	↑	Normal	↑	↓	↑	Neg or ↑
Lactate	Normal	Normal	↑	Slight ↑	NL or ↑	↑↑
Glucose	Variable	Normal	↓	↓	NL or ↑	NL or ↓
NH_4^+	NL or ↑	↑↑	Normal	↑	NL or ↑	NL or ↑
FTT	Yes	Yes	Yes	No	Yes	Yes
Dev Delay	Yes	Yes	No	No	Yes	Yes

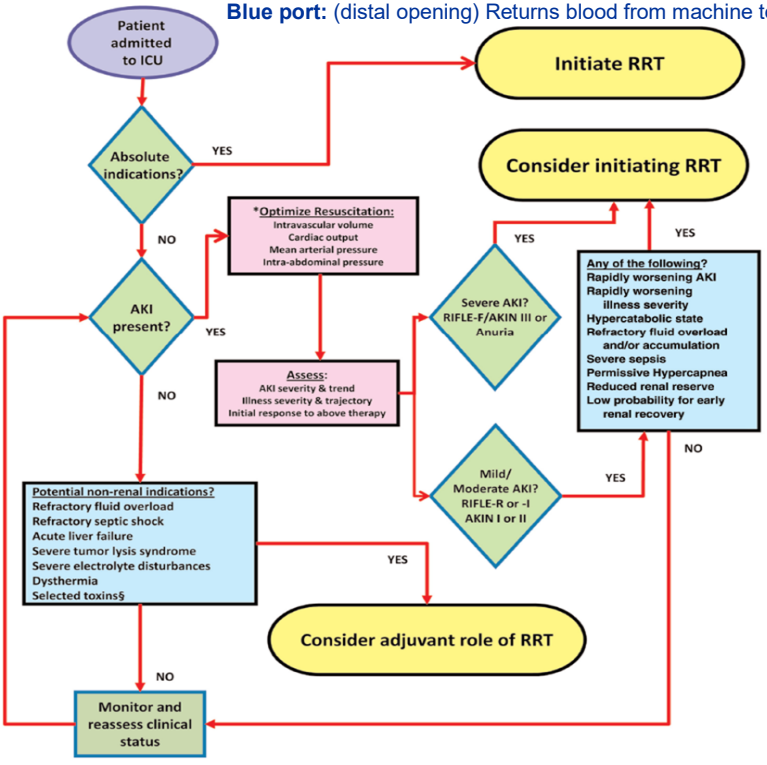
Renal Failure Etiology					
	BUN / Cr	**F_ENa**	**RFI**	**UNa**	**Spec Gravity**
Pre-Renal	**> 20**	**< 1%**	**< 1%**	**<20 mEq/L**	**High**
Renal	**< 20**	**> 1%**	**> 1%**	**>40 mEq/L**	**Low**

Renal Failure Index: RFI = Una/(UCr/SCr), Urine Na < 25 mEq/L is consistent with ↓ intravascular volume
Workup: BMP, Urinalysis, Renal U/S, F_ENa, CBC, Complement (C3, C4, CH50), ASO, Uric acid

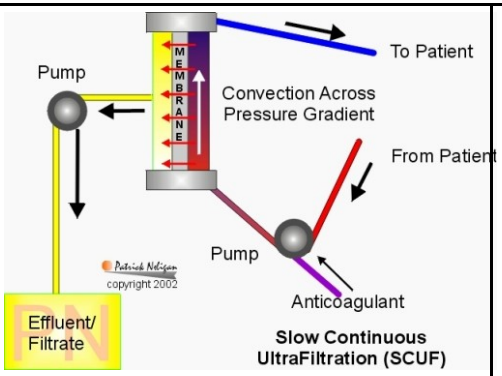
pRIFLE: R, Risk: eCCl ↓ 25%, UOP < 0.5 mL/kg/hr x8hrs, **I, Injury**: eCCl ↓ 50% UOP < 0.5 mL/kg/hr x16hrs, **F Failure**: eCCl ↓ 75%, UOP < 0.3 mL/kg/hr x12hrs, **L Loss**: > 4 weeks, **E, End-stage**: > 3months
KDIGO: Stage 1: 1.5-2 x ↑ in Cr, UOP < 0.5 ml/kg/hr 6-12 hr, **Stage 2:** 2-3 x ↑ in Cr, UOP < 0.5 ml/kg/hr >12 hr, **Stage 3:** >3 x ↑ in Cr or Cr> 4 or CVVH, UOP < 0.3 ml/kg/hr >24hr or anuria >12hr

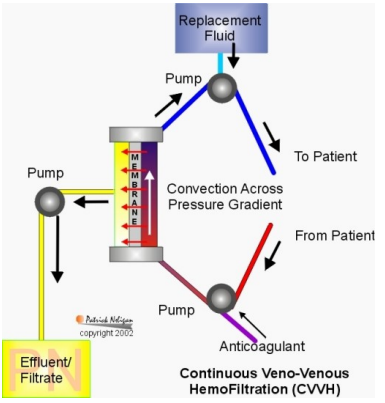
Continuous Renal Replacement Therapy				
Indications	**Technique**	**Clearance**		**Replacement fluid**
		Convection	**Diffusion**	
Azotemia/Uremia Toxic ingestions Electrolyte abnormalities Acidosis Oliguria/Anuria Fluid overload Rhabdomyolysis	**SCUF**	**+**	**-**	**-**
	CVVH	**++++**	**-**	**+++**
	CVVHDF	**+++**	**+++**	**++**
	CVVHD	**+**	**++++**	**-**

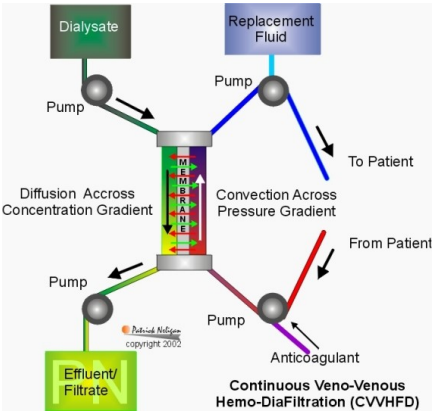
Red port: (proximal/side opening) Draws blood from the body
Blue port: (distal opening) Returns blood from machine to patient

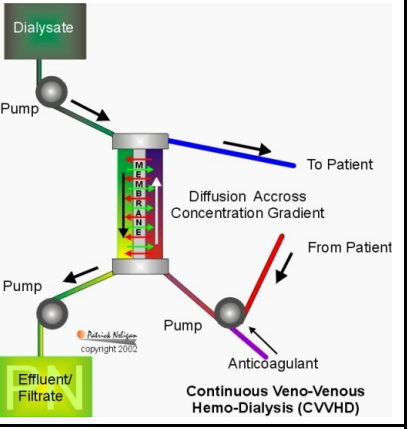


Yale Continuous Renal Replacement Therapy









Machine	Gambro PrismaFlex
Modality	CVVHDF
Hemofilter	HF1000, M60
Blood flow rate	3 to 5 mL/kg/min (50-200 mL/min)
Anticoagulant	Citrate: 1.5 x BFR in mL/hr
Calcium chloride	0.4 x (citrate infusion rate)
Pre-filter fluid replacement	20 mL/kg/hr
Post-filter fluid replacement	50 to 200 mL/hr
Dialysis fluid rate	20 mL/kg/hr
Net ultrafiltration rate	0.5 to 2 mL/kg/hr

Fluid and Electrolyte Equations

BSA = √[Ht(cm) x Wt(kg)] / 3600
FE_{Na} = (UNa)(PCr) / (PNa)(UCr) (Prerenal <1%, ATN >1%, postrenal >4%)
CrCl = (k)(Ht)/(PCr) (k=0.45< 1yr, 0.55 children & girl teens, 0.7 for boys)
Free Water Deficit = (0.6)(body wt in kg)[((Plasma Na)/140) – 1]
GIR (5-8 mg/kg/min) = [rate (ml/hr) x (% Dextrose) x (0.1667)] / (wt in kg)
Serum Osm = (2)(Na) + Glu/18 + BUN/2.8 (normal 270-295 mOsm/L)

YNHH LIVER TRANSPLANT POST-OP ORDER SET

Admit: NPO, VS q1hr, JP to self suction, Foley to gravity, OGT to LCWS, Wean vent as possible, goal to extubate as soon as possible
A-Line: NS with ½ U Heparin/mL at 3 mL/hr CVL: NS at 3 ml/hr with Maintenance fluids: D5 ½ NS JP replacement: 1 mL to 1 mL with 5% albumin
Immunosuppression per Liver team
Labs: CBC, Coags, Fibrinogen, ABG, Lactate, iCal, CMP, divalents, amylase/lipase; q4hr x24hrs, then q8hrs x24hrs, then q12hrs
CXR on admission and daily Liver U/S with doppler POD 1,2,3 in AM

Acute Liver Failure Labs

Initial: AST, ALT, AlkPhos, GGT, Tot Bili, Direct Bili, PT/INT, NH_4
Secondary: Hepatitis panel, Tylenol level, Anti-LKM, Anti-SMA, LDH, ceruloplasmin, lactate, total protein, albumin, amylase, lipase, lactate/pyruvate ratio of 10-20/1

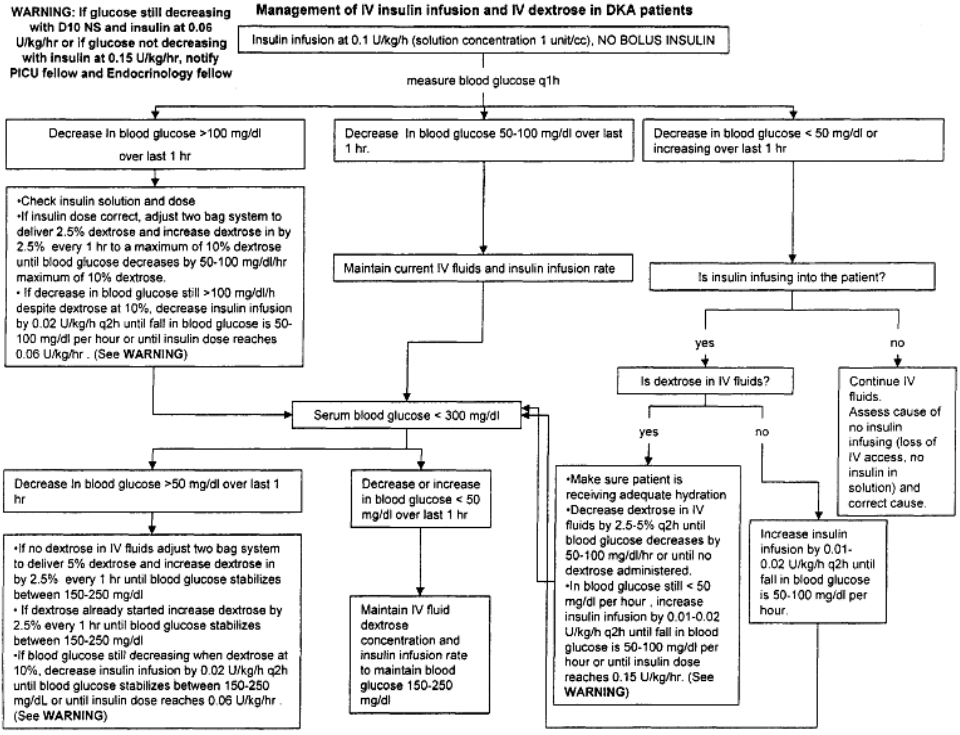
INGESTIONS AND POISONINGS

Assure airway protection for depressed level of consciousness and caustics. No Ipecac. Gastric lavage only if within 1-2 hours of ingestion. No sorbitol in <1yr. **Activated Charcoal** 1 g/kg (Max 50g): Must be administered immediately for xenobiotics ***NOT*** alcohols, iron, lithium, hydrocarbons, electrolyte solutions, and strong acids and bases. *Consider:* **MDAC 0.5 g/kg q6 for 24 hr** for delayed release carbamazepine, dapsone, phenobarbital, quinine, theophylline or xenobiotics that undergo enterohepatic recirculation. **Poison control: 1-800-222-1222,** Toxicology: Dr. Baum: 203-641-TOXI

Toxicant	Antidote: Dose
Acetaminophen (>150 mg/kg)	**N-Acetylcysteine**: IV: 150 mg/kg 60 min, 12.5mg/kg/hr x4hrs, 6.35 mg/kg/hr x16 hr PO: 140 mg/kg x1 then 70 mg/kg q4 for 17 doses
Anticholinergics	**Physostigmine** IV: Children: 0.02 mg/kg (max 0.5 mg) q5 min, Adults: 1 to 2 mg q5 min
Benzodiazepines	**Flumazenil** IV: 0.01 mg/kg IV (max 0.2 mg) q1 min
Beta blockers	**Insulin** IV: 1U/kg bolus and 0.5U/kg infusion (max 10 U/kg/hr) D10-50 for glucose ~200 **Glucagon** IV: 0.05 mg/kg IV/IM slow IVP (max 10 mg), **Transcutaneous/jugular pacing**
Ca^{2+} Channel blockers	**Calcium gluconate** IV: 60 mg/kg (max 3g) *OR* 10% **Calcium Chloride** 20 mg/kg (max 1g) **Insulin** IV: 1U/kg bolus and 0.5U/kg infusion (max 10 U/kg/hr) D10-50 for glucose ~200 **Glucagon** IV: 0.05 mg/kg IV/IM slow IVP (max 10 mg), **Transcutaneous/jugular pacing**
Carbon Monoxide	100% FiO_2 ($t_{1/2}$ reduced from 5 to 1 hr) until CO-Hgb<5%, *Consider* hyperbaric O_2
Cholinesterase Inhibitors Organophosphates, carbamates	**Atropine** IV/IM: Children: 0.05-1mg/kg, Adolescents: 1-3mg/kg, Adults: 1-5mg/kg q3 min **Diazepam** IV/IO: Child: 0.2-0.5 mg/kg (max 5mg), Adult: 5-10 mg/kg (max 30 mg) q15 min **Pralidoxamine** IV: 20-50 mg/kg (max 2g) over 45 min then 10-20mg/kg/hr (max 500mg/hr) Auto-Injectors (Duodote, ATNAA, Mark-1): Atropine: 2mg, Pralidoxamine: 600 mg
Cyanide	**Hydroxocabalamin** (Cyanokit) IV: 70 mg/kg (max 5g) over 15 min (discolors urine/plasma)
Digoxin (Oleander, Squill)	**Digoxin antibody** dosed in vials: Vials = [dig level (ng/mL)]x(wt in kg)/100 *OR* 10-20 vials
Ethylene glycol/methanol	**Fomepizole** IV: 15 mg/kg/dose IV load over 30 min then 10 mg/kg q12hr x4 doses, **Folate**
Iron	**Deferoxamine** IV: 15 mg/kg/hr (max 6g in 24hr) *OR* 50 mg/kg IM (max 1 gram)
Isoniazid	**Pyridoxine** IV: 1gm:1gm of INH ingested up to 70 mg/kg (max 5g) at 0.5g/min then 4 hrs
Lead (>70 ug/dL)	**BAL (Dimercaprol) IM**: 4 mg/kg q4hr, Ca-EDTA IM/IV: 50 mg/kg/day x5 days (max 1g/d) **DMSA (Sucimer)** PO: 10 mg/kg (max 1.5 g/d) q8 x5 day followed by q12hr for 14 d
Lipid soluble anesthetics (cardiac arrest)	**20% Lipid (intralipid)** IV: 1.5 mL/kg IVP q1min followed by 0.5 mL/kg/min (max 8 mL/kg)
Methemoglobinemia	**Methylene blue** IV: 1 mg/kg over 30 min repeated in 1 hour if needed
Opiates/Clonidine	**Naloxone** IV/IO/IM/SC/ETT: Partial: 0.001 mg/kg Full: 0.1 mg/kg (max 2 mg) q 2min (cumulative max dose of 10 mg) then infusion 0.002-0.2 mg/kg/hr Autoinjector: Child: 0.4 mg, Adult: 2 mg q2 min; IN Child: 2mg, Adult: 4mg
Na channel blockers (TCA)	**$NaHCO_3$** IV:1-2 mEq/kg q5 min to pH 7.5 if QRS >100ms
Sulfonylurea (Hypoglycemia)	**Octreotide SC**: 1.25 ug/kg (max 50 ug) q6 hrs *OR* IV 1-2 ug/kg then 1-2 ug/kg/hr
Valproic Acid (Hyperammonemia)	**L-Carnitine** IV: 100 mg/kg (max 6 g) x1 then 15 mg/kg q6 hr (max 3g)

DIABETIC KETOACIDOSIS

NS 20 mL/kg as needed for fluid resuscitation, place foley
Send VBG, Lytes, TSH, Insulin, CBC, HA1c, Gliadin-Ab, GAD65-Ab, TTG, Islet cell-Ab, C-peptide, Insulin-Ab, Anti-512-Ab (*Avg Plasma Glu = (HbA1c)(35.6)-77.3*)
Start **insulin infusion**; 0.1 U/kg/hr, CFR = MF + ½ (Calc deficit replaced over 24 hours)
↑ Risk of cerebral edema: 1. Younger age. 2. New Diagnosis. 3. Severity of acidosis at presentation. 4. Failure of Na to rise with Glu correction. 5. ↑ BUN. 6. Bicarb use



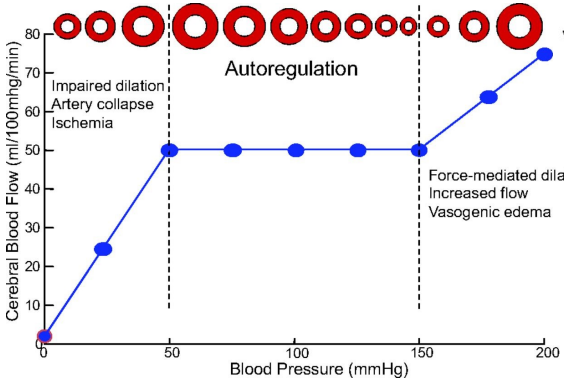
Adrenal Crisis (stress dose): Hydrocortisone 50-100 mg/m^2/day divided q6

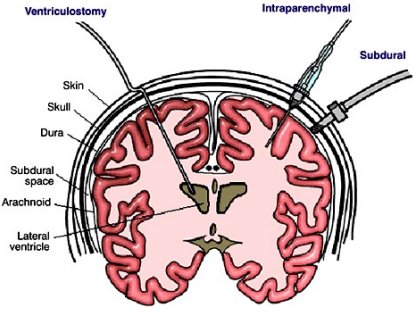
ACTH Stim Test: Cosyntropin 250 mcg over 2 minutes (125 mcg <2y) and draw cortisol at 0, 30, 60 minutes. Stop steroids if cortisol rise >9 mcg/dL or >34 mcg/dL
Hydrocortisone IV: 2 mg/kg (max 100 mg) then ÷q6 (Physiologic is 8 mg/m^2/day)
Fludrocortisone PO: (Florinef, more mineralocorticoid activity): 0.05 mg q24

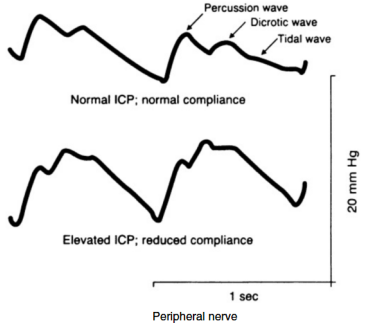
HYPONATREMIA DIFFERENTIAL

	Serum Osm	Urine Osm	FENa	Fluid status	Treatment
↑ H2O intake	280-300	Low < 100, SG < 1.003	Low <1%	Volume overload	Restrict free water
SIADH	Low < 275, Serum Na<135	High > 100, SG > 1.005	High >3%, Urine Na >30	Euvolemic	Fluid restrict, loop diuretics
CSW	High >280	High >100	High >3%	Hypovolemic	NS hydration
CHF or ALF	Low < 275	Normal	Low >1%	Volume overload	↓ Na load

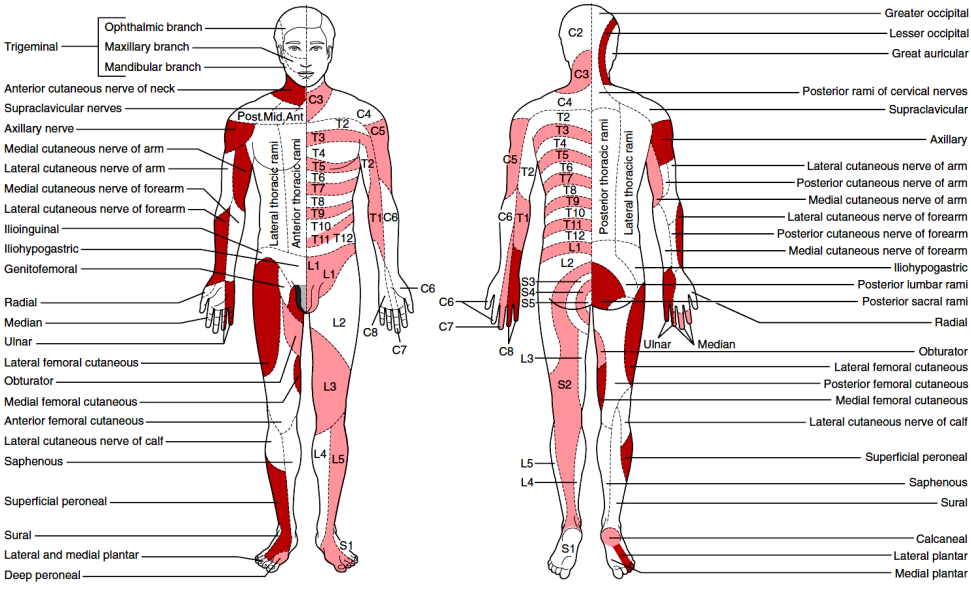
NEUROLOGY







Nerve Roots



INCREASED ICP

Cerebral perfusion pressure = MAP – (ICP, CVP or ITP), CBF= 20 mL/100g/min
Keep head midline, elevate HOB to 30°, Maintain $PaCO_2$ 30-35 (acute only), control fever with Tylenol/cooling blankets, opiods for sedation, Paralyze, follow UOP.
Goal ICP <20. Maintain **CPP >40 (<1yr), >50 (1-10yr), >60 (>10yr)**
Mannitol: 0.5-1 g/kg slow IV push – If serum osmol <320
3% saline: 3-5 mL/kg over 30-60 minutes – If serum osmol >320
Pentobarbital Coma: 10 mg/kg load then infusion at 1-6 mg/kg/hour
Spinal Cord Injury: Solumedrol: 30 mg/kg in D5W then 5.4 mg/kg/hr for 23hr

GLASGOW COMA SCALE MODIFIED FOR CHILDREN

Eye Opening	Verbal Response	Motor Response	
No response	No response	No response	1
To pain	Moans to pain, inaudible sound	Decerebrate/Extension posturing	2
To verbal stim	Cries to pain, inappropriate words	Decorticate /Flexion to pain	3
Spontaneous	Irritable cries, confused	Withdraws to pain	4
	Coos or babbles, oriented, appropriate	Withdraws to touch, localizes pain	5
		Moves spontaneously, purposefully, obeys commands	6

PEDIATRIC STROKE

Call 203-688-3111 to activate Acute Stroke Team
Vitals, D-stick, NPO, HOB flat, NS at M, **ASA 5 mg/kg** if no bleed

STAT head CT, Brain MRI on 3T scanner, MRV head, CT angiogram

Chem7, CBC, Coags, CK, UTox, Lipids, Lac, Pyruvate, Urine OA, Serum AA
Hyper-Coag: fibrinogen, AT III, protein C, D-dimer, homocysteine, F5 Leiden, β-2-cardiolipin, PA-1 mut.

SEIZURES

Check Dextrose, Lytes, Ca, Mg, Phos, AED Levels, CBC, LFTs, NH_4, Toxicology, CT, LP
ABCs, 100% FiO_2, Secure airway, treat fever, treat aggressively with AEDs if >15min

5-10 min	**Keppra: 20 mg/kg load** (max 60 mg/kg or 4.5 g) followed by 10 mg/kg BID **Lorazepam (Ativan)**: IV/IM: 0.1 mg/kg/ over 2 minutes (max 5 mg) OR **Diazepam (Valium)**: IV: 0.2 mg/kg (max 10 mg) *OR* PR:0.5 mg/kg (max 20 mg) OR **Midazolam (Versed)**: IV/IM/IN: 0.2 mg/kg (max 10 mg)
10-30 min	Repeat **Benzodiazepines** every 5 to 10 minutes up to 3 times. Then try: **Fosphenytoin**: 20 mg/kg over 10 minutes (Watch low BP) repeat 5-10 mg/kg dose
30-60 min	**Phenobarbital:** 15 mg/kg over 10 min q15 min (max 40 mg/kg or 1g) Infusion at 1 mg/kg/min. Consider emergent EEG
>60 min	**Pentobarbital**: 10 mg/kg load then infusion at 1-6 mg/kg/hour **Midazolam**: 0.15 mg/kg load then infusion at 2-6 mg/kg/hour **Propofol**: 1-2 mg/kg load (Watch low BP) then infusion at 3-10 mg/kg/hour Titrate drips to cessation of seizure activity and burst suppression on EEG

Levels: Levetiracetam 12-46 ug/mL, Carbamazepine: 6-12 ug/mL, Ethosuximide 40-100 ug/mL, Lamotrogine 2-16 ug/mL, Phenobarbital 15-30 ug/mL, Phenytoin 10-20 ug/mL, Valproic acid 50-150 ug/mL, Zonisamide 10-40 ug/mL

PICU SEVERE TBI MANAGEMENT ALGORITHM

MONITOR
Continuous: CRM, $ETCO_2$, T°
Admission labs:
Blood gas CBC Type & Screen
Chem 10 FGN Coag panel
Labs for first 24 hours:
- Chem 10 Q 4-6 hr
- Blood gas, CBC, Coags Q8 hr

AVOID
Hypoventilation $PaCO_2$ > 45 mmHg
Hypoxia PaO_2 < 65mmHg
Hypotension
Hyperthermia (> 38° C)
Hypothermia (< 32° C)
Hypoglycemia (< 60mg/dL)
Hyperglycemia (> 120 mg/dL)
Hyponatremia (< 140)

Cerebral herniation S&S:
- Hypertension
- Bradycardia
- Abnormal respiratory pattern
- Fixed and dilated pupils
  - Unilateral or Bilateral

Cerebral Herniation Treatment
- Elevate HOB to 30 degrees
- Hyperventilate (manual)
- 3% hypertonic saline:
  2-4 mEq/kg (4-8 mL/kg) IV given over 5 min.
  Or
  Mannitol 0.25-1 g/kg IV (5 min)

GCS ≤ 8
Abnormal head CT

Surgical intervention if indicated

Intraventricular ICP monitor

Head midline, C-collar not tight
HOB @30° OR Reverse Trendelenberg if Spinal cord injury

Maintain age appropriate CPP
- Euvolemia
  Fluid resuscitation
- Vasoactive agents

Age specific CPP
< 2 yrs – 40 mmHg
2-4 yrs – 50
5-9 yrs – 60
> 10 yrs – 65

Maintain normoventilation:
pCO_2 35 – 40 cmH_20

Maintain euvolemia:
- Exam, Heart rate
- CVP 8-12 mmHg
- Urine output

ICP > 20

Sedation & Analgesia

CHOICES
Narcotics
Benzodiazepines
Dexmedetomidine
Propofol (24 hr intervals)

ICP > 20

If ventriculostomy – drain CSF

CONSIDER
- Mild hypothermia 32°-34° C
- Scheduled Tylenol Q6 hr
- Lidocaine 1mg/kg IV prior to ETT suctioning

ICP > 20

Hyperosmolar therapy
Option:
- 3% saline: 1-4 mEq/kg (2-8mL/kg) over 10 min.
- Then consider 3% saline infusion
- @ 0.5–1 mEq/kg/hr
- May repeat if serum osm < 360

OR

Option:
Mannitol 0.25 – 1 g/kg PRN
If serum osm < 320

ICP > 20

Neuromuscular Blockade

ICP > 20

Barbiturates (Intermittent or Continuous)

ICP > 20

Mild hyperventilation
$PaCO_2$ 30-35 mmHg

Refractory ICP > 20

CONSIDER
Surgical Intervention

Second tier of therapy

Obtain CT Scan

→ **If unilateral swelling, consider unilateral decompressive craniotomy**

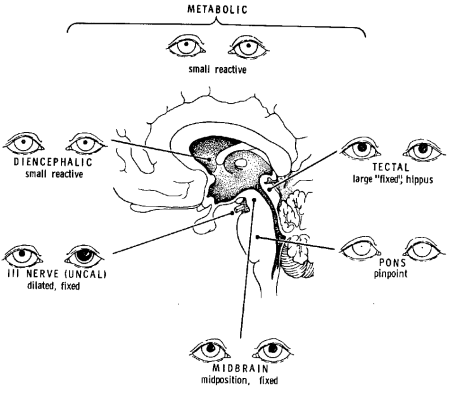
→ **If bilateral swelling, consider bilateral decompressive craniotomy**

→ **If evidence of ischemia, consider moderate hypothermia (32°-34° C)**

→ **If evidence of hyperemia, consider hyperventilation ($PaCO_2$ < 30 mmHg)**

→ **If working ventriculostomy and open cisterns, consider lumbar drain**

PEDIATRIC TRAUMA SCORE			
Category	**+2**	**+1**	**-1**
Size	> 20 kg	10 – 20 kg	< 10 kg
Airway	Normal	Maintainable	Not Maintained
Systolic BP	>90 mmHg	50-90 mmHg	<50 mmHg
CNS	Awake	Obtunded	Comatose
Open Wound	None	Minor	Major
Skeletal	None	Closed Fracture	Open or Multiple fractures
>8 less than 1% mortality, < 8 Trauma center 4 predicts 50% mortality, < 1 predicts 98% mortality			



Brain Death Testing

Presence of identifiable and irreversible injury, **GCS = 3**
Correct other causes AMS: SBP nl, T>35, No sedatives (Pheno <40 mg/L, Pento <5 mg/L)
2 Exams separated by more than 24 hours; EEG and CBF Angiography are ancillary tests

Pupilary light reflex	**A: II**	**E: III**
Occulocephalic reflex	**A: VIII, IX, XI**	**E: III, IV, VI**
Cold caloric reflex (HOB 30°)	**A: VII**	**E: III, IV, VI**
Corneal reflex	**A: V**	**E: VII**
Gag, Cough reflex	**A: IX**	**E: X**

Apnea Test: Pre-oxygenate, obtain baseline $PaCO_2$, Monitor SpO_2, BP, HR
Pause vent: Observe resp effort until $PaCO_2$>60 **and** >20 from baseline or SpO_2>85%

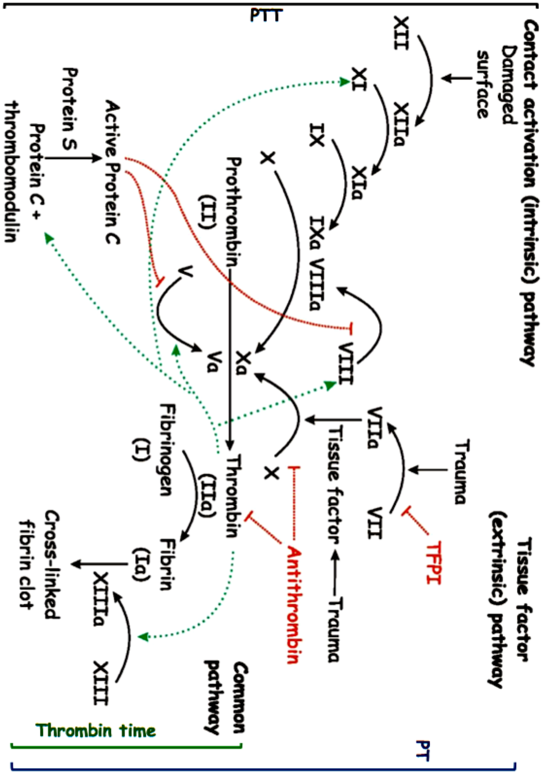
End of life care

Identify yourself and the patient. "I'm sorry for your loss. Is there anyone I can call for you?"
"What questions do you have?" "Take all the time you require."
Wean hemodynamic support first, hypotension is sedating and rarely causes symptoms
Bad pulmonary disease leading to hypoxia and hypercarbia present difficult symptoms

Pain	Massage, reposition, distraction, **Tylenol, motrin, ketorolac** **Morphine, Hydromorphone** titrated to effect **Intranasal Fentanyl** 1 mcg/kg IN q1hr
Secretions	Fluid restriction, gentle suctioning **Glycopyrrolate**: 0.01-0.02 mg/kg IV or 0.05-0.1 mg/kg PO q4hr **Atropine**: 0.01-0.02 mg/kg PO (max 0.4 mg) **Scopolamine Patch**: 6-12y: ½ patch q3days, >12 1 patch q3days
Dyspnea	Elevate HOB, Bedside fan to face, gentle suction, fluid restrict, O_2 **Morphine**: 0.15 mk/kg PO q2hr, **Lorezapam**: 0.05 mg/kg PO q6hr
Agitation	Familiar people, low light, soothing tones, music, good sleep **Lorezapam**: 0.05 mg/kg PO q2hr PRN **Haloperidol**: 0.05 mg/kg PO/IV/IM q4-6hr PRN
Nausea Emesis	Avoid irritating foods/smells **Ondansetron:** 0.15 mg/kg IV q6hrs, **Granisetron**: 0.1 mg/kg IV q8hr **Metoclopramide**: 0.01-0.02 mg/kg IV q4hr, **Lorazepam**: 0.05 mg/kg **Diphenhydramine:** 0.5-1 mg/kg/dose PO/IV q4hrs

Livertox.nih.gov

Age corrected normal hematologic values								
Age	Hgb (g%)	Hct (%)	MCV (fL)	MCHC (g/%RBC)	Retic (%)	WBC / µL×100 (avg)	% Neut	Plts (10^3/µL)
32 wGA	14-15	45-47	120	32	3-10	-	-	280±70
1 d	16.8-21.2	57-68	110-128	29.7-33.5	1.8-4.6	7-35 (18)	45-85	310±68
1 wk	15-19.6	46-62	107-129	30.4-33.6	0.1-0.9	4-20 (10)	30-50	-
1 m	11.1-14.3	31-41	93-109	33.3-36.5	0.1-1.7	6-18 (10)	30-50	-
3-5 m	10.4-12.2	33	80-96	31.8-36.2	0.4-1	6-17 (10)	30-50	300±50
6-11 m	11.8	35	77	33	0.7-2.3	6-16 (10)	30-50	-
1 yr	11.2	35	78	32	0.6-1.7	6-15 (10)	30-50	-
2-10yr	12.8	37	80	34	0.5-1	7-13 (9)	35-60	-
11-15yr	13.4	39	82	34	0.5-1	5-12 (8.5)	40-60	
Adult M	16 ± 2	47±7	91	34	0.8-2.5	4.3-10 (7)	25-62	300±50
Adult F	14 ±2	42 ± 5	82-101	31.5-36	0.8-4.1	4.3-10 (7)	25-62	300±50



FACTORS (Vit. K dependent, *ALF)			
	$t_{1/2}$ (hr)	mg/L	Comments
I: Fibrinogen	90	3000	Adhesion protein that forms clot
II: Prothrombin	65	100	Requires Ca^{2+} for activation, Serine protease
III: Tissue Factor			Lipoprotein initiator
V: Labile factor *	15	10	Cofactor
VII: Proconvertin *	5	0.5	Requires Ca^{2+} for activation, Serine protease
VIII: Antihaemophilic factor *	10	0.1	Produced by **endothelial cells** Circulated bound to vWBF
IX: Christmas	25	5	Requires Ca^{2+} for activation, Serine protease
X: Stuart-Power	40	10	Requires Ca^{2+} for activation, Serine protease
XI: Plasma thromboplastin antecedent	45	5	Serine protease
XII: Hageman			Serine protease
XIII: Fibrin stabilizing	200	30	Transamidase that cross-links clot
Protein C	6	4	Cleaves factors Va and VIIIa
Protein S	60	110	Cofactor for Protein C
Antithrombin	17-76	120	Inhibits factors XII, XI, IX, X, thrombin

Massive Transfusion Protocol (Blood Bank: 688-2443)

Wt	IV
1-5 kg	22-24 g
6-10 kg	20-24 g
11-25 kg	18-22 g
25-50 kg	16-20 g

Other considerations: Admit Weight, Continuous VS, warm to normal temp. Limit crystalloid to avoid dilutional coagulopathy, Labs: T&S, CBC, PT/INR, PTT, Fibrin., Lytes, BUN/Cr, iCal, ABG, lac
Antifibrinolytic: **Amicar 100 mg/kg bolus and infusion 33 mg/kg/hr**
Call for help: Surgery, OR, Anesthesia and Blood bank

Product	Threshold	Dose
pRBC (~360 mL/unit)	**Variable**	**30 mL/kg**
FFP (~250 mL/unit)	**INR > 1.5**	**20 mL/kg**
Platelets (~50 mL/unit)	**> 100, 000**	**20 mL/kg**
Cryo (~15 mL/unit)	**Fibrinogen >100**	**0.2 units/kg**

1. Identify & mange bleeding: Surgery, Angiography, embolization or endoscopy
2. Clinical team activates MTP: Call Blood bank with MR, age, wt, sex and room number, order MTP in EPIC, send PCA as a runner
3. Obtain MTP Pack per weight, **TRANSFUSE 1:1:1 RATIO**

Bleeding stops: Stop MTP, notify blood bank, return unused product, send labs	**Bleeding continues**: Send labs, notify blood bank to send another MTP pack, **rFVIIa 90 mcg/kg/dose**

FLUID AND BLOOD PRODUCTS

Blood Volume: Preemie: 100 mL/kg, NB: 90 mL/kg, 6 m/o: 80 mL/kg, >10 y/o: 70 mL/kg

Albumin 5%	10-20 ml/kg	Use for hypovolemia & volume expansion
pRBCs	10-20 mL/kg over ½ hr	10 mL/kg will raise Hgb by ~2.5 g/dL
Platelets	6 units/m2 over 30m	1 pharesis unit = 6 random units 1 U/m2 will raise Plts by 10-50k
FFP	10-15 mL/kg over 30 min	Contains all clotting factors (↓ BP if push) Replaces 20-30% of factors
Cryoprecipate	1-2 units/10 kg	Insoluble fraction of FFP at 1°C Only factor VIII, XIII, vWF, fibrinogen
Vitamin K	5-10 mg IV	Give to correct PT
Antithrombin III	Consider when up-titrating heparin dose, especially in infants (normal activity 80-120%) Dose IU = [Desired-Measured activity]x(wt in kg)/1.5 (1 U/kg should ↑ activity by 1.5%)	
Protamine	Reverses heparin, dose to neutralize 100U of heparin depends on interval (max 50mg): Immediate: 1-1.5 mg/100U, 0.5-1 hr: 0.5 to .75,mg/100U >2 hr: 0.25 mg/100U	
Factor VIIa	45-90 mcg/kg IV	Use for severe uncontrollable bleeding

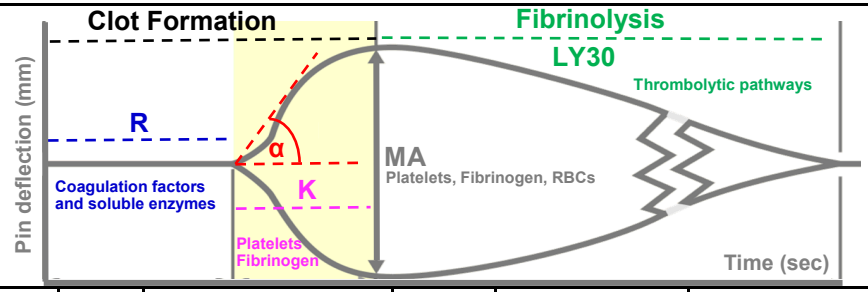
HYPERCOAGULABLE WORK UP

CBC, Coags, Protein C/S activity, Anti-thrombin III, Factor V Leiden, Prothrombin 20210, homocysteine, MTHFR, lipoprotein A, Factor VIII level, Cardiolipin Abs, APC resistance

BLEEDING TEST INTERPRETATION

PT	PTT	Congenital	Acquired
Increased	Normal	VII deficiency	Liver dis., Vitamin K deficiency
Normal	**Increased**	VIII, IX, XI deficiency	VIII inhibitor, Lupus
Increased	**Increased**	II, V, X def, FGN, vWD	DIC, ALF
Normal	Normal	Platelets? Send TEG?	

TEG Interpretation



Process	Variable	Definition	Normal	Low value	High value
Clotting time	**R** (CT)	Reaction time to first fibrin strand formation,	**5-10 min**	Overactive factors **Anticoagulate**	Factor def., excess heparin **Give FFP or protamine**
Clot kinetics	**K** or **α**	Rate of clot formation (α) or time to specific strength (K)	**α: 53-72°** **K: 1-3 min**	Fibrinogen or plt def. **Give CRYO, FFP**	Platelet hypercoagulability **No treatment**
Clot strength	**MA**	Maximum amplitude of clot strength	**53-72 mm**	Low plts or fibrinogen, or plts dysfunction **Give Platelets or DDAVP or CRYO**	Platelet hypercoagulability **No treatment or give antiplatelet agent**
G is MA converted to an elastic modulus **C.I.** is a liner combination of R, K, α & MA			**G: 6 - 13** **CI: -3 - 3**		
Clot stability	**LY30**	Amount of clot lysis in 30 min	**0-8%**		Excess fibrinolysis **Give transexamic acid**

Hematologic/Oncologic Emergencies

Dysfunctional uterine bleeding (Hgb <7 g/dL)	**PREG TEST**, then **Conjugated Estrogen** IV: 25 mg q6hrs for 6 doses or bleeding stops. Consider: **Tranexamic acid PO**: 1300mg q8hr, **Aminocaproic acid IV/PO**: 5g than 1g/hr, **Desmopressin** (DDAVP) IV: 0.3 mcg/kg over 30 min
Bleeding Diatheses	**Aminocaproic acid PO:** 50 mg/kg q6hr (max 24 g/day), **Antihemophilic factor IV**: 50-80 U/kg q8hr for 3 days to keep VWF/Roc>50%, **Tranexamic acid IV:** Load: 10-30 mg/kg (max 100 mg/kg or 1g) infusion at 5 to 10 mg/kg/hour, **DDAVP IV:**0.3 mcg/kg over 30 min , **IN:** 150ug for <50kg, 300ug for >50kg, **Factor VIIa IV:** 90 ug/kg q2hr (minor bleeding 15-30 ug/kg), **Factor VIII** (**Hemophilia A**) **IV:** Dose=(Wt in kg)x(desired level of correction)x(0.5), **Factor IX** (**Hemophilia B**) **IV:** Dose=(Wt in kg)x(desired level of correction)x(1.4)
Tumor lysis syndrome	Uric acid >8 mg/dL, K >6 mEq/L, PO_4^- > 6.5 (child), 4.5 (adult), Ca^{2+} >7 mg/dL Hydration: MIVF 2-3 L/m^2 per day titrated to UOP 2-6 mL/kg/hr, **Furosemide** IV: 1 mg/kg q6 **Allopurinol** (uric acid <7 mg/dL) PO: 3.33 mg/kg q8hr (max 300 mg) **Rasburicase** (uric acid >8 mg/dL or AKI) IV: 0.15-0.2 mg/kg for up to 5 doses **Treat ↑ K:** Dextrose 1-2 g/kg IV with Insulin 0.1 U/kg IV, CaCl2 10 -20 mg/kg IV, Albuterol, $NaHCO_3$ 1-2 mEq/kg, Kayexalate: 1-2g/kg/dose NG/PR, Lasix, Dialysis
Hyperleukocytosis AML~200, ALL~400	WBC >100,000 cells/uL or Blasts >75,000 cells/uL, 2x MIVF w/o K, Cytoreductive chemotherapy, **Hydroxyurea** PO: 50-100 mg/kg/day, *Consider* Leukopheresis
Hemophagocytic Lymphohistiocytosis	Five of: Fever, Splenomegaly, Cytopenias, ↑ Triglycerides, ↓ Fibrinogen, Ferritin > 500, ↑ sCD25(IL-2), ↓ NK cytotoxicity or **+** BMA. **Dexamethasone/Etoposide**, **Cyclosporine, ATG, Alemtuzumab**
Tumor compression syndromes	**Dexamethasone** IV: 1-2 mg/kg load (max 16 mg) followed by 0.25-0.5 mg/kg q6 *Consider* **Acetazolamide** IV/PO: 5 to 15 mg/kg q8 (max 1g/day) if ↑ ICP

SIRS CRITERIA (Pediatric patients)

Temp	>38.5 or <36.0	**RR**	>2SD above mean for age
HR	>2SD above mean for age	**WBC**	<5 or >15 or >15% bands

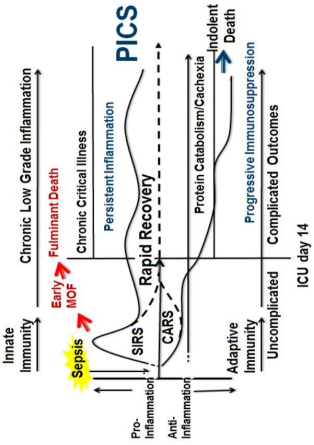
Must have 2 of 4 to diagnose SIRS, **SEPSIS**: SIRS plus suspected/proven infection
SEVERE SEPSIS: Sepsis plus end-organ dysfunction, **SEPTIC SHOCK**: Sepsis plus CV dysfunction. (Hypotension, Oliguria, Cap refill > 5 sec, Lactate > 2)

Pediatric Logistic Organ Dysfunction Score (PELOD-2)								
Variable		0	1	2	3	4	5	6
GCS		> 11	5-10			3-4		
Pupils		Both reactive					Both fixed	
Lactate		< 5	5-10.9			> 11		
Mean Art. Pressure Age (months)	0-1	> 46		31-45	17-30			< 16
	1-11	> 55		39-54	25-38			< 24
	12-23	> 60		44-59	31-43			< 30
	24-59	> 62		46-61	32-44			< 31
	60-143	> 65		49-64	36-48			< 35
	>144	> 67		52-66	38-51			<37
Serum Creatinine Age (months)	0-1	< 0.78		> 0.79				
	1-11	< 0.25		> 0.26				
	12-23	< 0.38		> 0.39				
	24-59	< 0.56		> 0.57				
	60-143	< 0.65		> 0.67				
	>144	< 1.04		> 1.05				
Pa_{O2}/Fi_{O2}		> 61		< 60				
Pa_{CO2}		< 58	59-94		> 95			
Mech. Vent		No			Yes			
WBC		> 2		< 2				
Plts		> 142	77-141	< 76				

If a variable is not measured it should be considered normal. If a variable is measured more than once in 24hrs the worst value is used.

Logit(mortality) = -6.61+0.47(PELOD score), Prob(Death)=1/(1+e^(Logit(mort))

PICS= Persistent Inflammation, Immuno-suppression, Catabolism Syndrome
MOF=Multiple Organ Failure
SIRS=Systemic Inflammatory Response Syndrome
CARS= Compensatory Anti-Inflammatory Response Syndrome



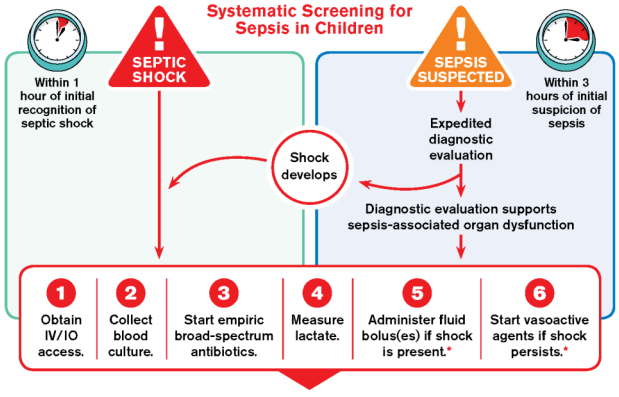
SEPSIS-3 (Adults) Sequential Organ Failure Assessment (SOFA) Score					
Organ System/Score	0	1	2	3	4
Respiration: PaO_2/FiO_2	> 400	≤ 400	≤ 300	≤ 200 w/MV	≤ 100 w/MV
Coag/Heme: Plt ct.	> 150	101-150	51-100	21-50	0-20
Hepatic: Bili (mg/dL)	< 1.2	1.2-1.9	2.0-5.9	6.0-11.9	> 12.0
CNS: GSC	15	13-14	10-12	6-9	< 6
Cardio: MAP (mmHg)	> 70	0-70	Dopa ≤ 5.0	Dopa 5-14 or Epi/Norepi ≤0.1	Dopa ≥15 or Epi/ Norepi >0.1
Renal: Cr (mg/dL) or	< 1.2	1.2-1.9	2.0-3.4	3.5-4.9	> 5.0
Urine output				< 500 mL/24h	< 200 mL/24h

qSOFA (0-3): 1 point for SBP < 100, RR < 22, GCS < 15

Sepsis: Life threatening organ dysfunction due to dysregulated response to infection
Increase in SOFA score of >= 2 points
Septic Shock: Subset of sepsis with severe circulatory/metabolic failure
Sepsis plus lactate > 2 or vasopressor requirement to maintain MAP >= 65

Initial Resuscitation Algorithm for Children

Surviving Sepsis Campaign



Respiratory support
Assess for Pediatric Acute Respiratory Distress Syndrome

Infectious source control — **Continuous reassessment** — Fluid and vasoactive titration*

Advanced hemodynamic monitoring if shock persists

- +/- hydrocortisone for refractory shock**
- Nutritional support
- Avoid hypoglycemia
- Antimicrobial stewardship

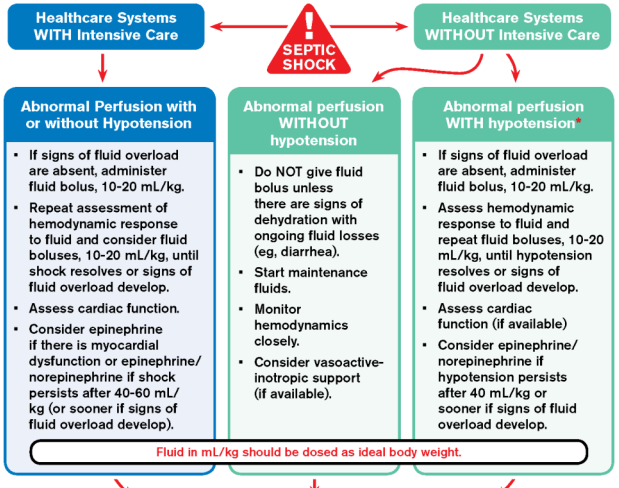
VA or VV ECLS for refractory shock or oxygenation/ventilation failure (after addressing other causes of shock and respiratory failure)

*See fluid and vasoactive algorithm. Note: Fluid bolus should be omitted from bundle if a) fluid overload is present or b) it is a low-resource setting without hypotension. Fluid in mL/kg should be dosed as ideal body weight.

**Hydrocortisone may produce benefit or harm.

Fluid and Vasoactive-Inotrope Management Algorithm For Children

Surviving Sepsis Campaign



Shock resolved, perfusion improved

- Do not give more fluid boluses.
- Consider maintenance fluids.
- Monitor for signs/symptoms of recurrent shock.

*Hypotension in healthcare systems WITHOUT intensive care is defined as either:

SBP	SBP	SBP	OR	Presence of all 3 World Health Organization criteria: cold extremities, prolonged capillary refill > 3 seconds, weak/fast pulse
< 50 mm Hg in children aged < 12 months	< 60 mm Hg in children aged 1 to 5 years	< 70 mm Hg in children aged > 5 years		

www.sccm.org/SurvivingSepsisCampaign/Guidelines/Pediatric-Patients

Emergent source control: Consider the abdomen (IAP<12 mmHg) and removing indwelling catheters. At Yale: **Vancomycin** 15 mg/kg (1g) and **Ceftazidime** 100 mg/kg (2g) or **Zosyn** 100 mg/kg (3.3g). Perform **cardiac ultrasound,** normalize **electrolytes** and consider early **NIV**. Titrate **fluid resuscitation** to markers of CO; HR, MAP, CRT, UOP, mental status, serum lactate and **vasoactive medications** to cardiac index 3.5-5.5 L/min/m^2, stroke index 30-60 mL/m^2, systemic vascular resistance 800-1600 dyne-s/cm^5/m^2, or central venous oxygen saturation ($ScvO_2$) > 70%. Consider **Hgb** >7 mg/dL and **Hydrocortisone:** 2 mg/kg (max 100mg) and **Insulin** is glucose is persistently > 200 mg/dL

Neonates: Prostaglandins until cardiogenic shock ruled out, titrate **Epinephrine** 0.05-0.3 to $S_{cv}O_2$>70%, SVC flow >40 mL/kg/min, consider **Dopamine** <10 ug/kg/min, **hydrocortisone** 2 mg/kg, **T_3 replacement** or **pentoxifylline** 5 mg/kg/hr for 6 hr

PHARMACY

Acetaminophen*	10-15 mg/kg/dose PO/PR q4h prn (NTE max 4 g/day or 90 mg/kg/day or less) 20-45 mg/kg PR x1 may be given
Acetazolamide*	**DIURESIS/URINE ALKALIZATION**: 5 mg/kg/day÷q24h PO/IV; **SEIZURES**: 8-30 mg/kg/day÷q6-12h PO (max 1 g/day); **PSEUDOTUMOR CEREBRI**: 25 mg/kg/day÷q6-24h PO (max 100 mg/kg/day)
Acyclovir**	HSV encephalitis: 60 mg/kg/day÷q8h IV **VZV/HSV**: 30 mg/kg/day÷q8h IV, 80 ng/kg/day÷ 3-5x/day PO (max 3.2 g/day)
Adenosine	0.1 mg/kg rapid IV/IO (max 6 mg/initial dose), if not effective repeat 0.2 mg/kg rapid IV/IO (max 12 mg/dose)
Albuterol	4-8 puffs MDI INH q20min x 3 or 0.5% inhalation solution: <10 kg: 1.25 mg = 0.25 mL INH q20min x 3 10-20 kg: 2.5 mg = 0.5 mL INH q20min x 3 >20kg: 5 mg = 1 mL, INH q20min x 3; then q1-6h prn, *continuous:*5-40 mg/hr
Alprostadil (prostaglandin E_{-1})	0.01-0.1 mCg/kg/min IV, titrate to response (max 0.4 mCg/kg/min)
Aminocaprionic Acid*	50-100 mg/kg IV x 1 then 30 mg/kg/h IV (max 30 g/day)
Amiodarone	**VF/VT** : 2.5-5 mg/kg IV/IO rapid push (max 15 mg/kg or 300 mg/dose), **ARRHYTH**: 2.5-5 mg/kg IV/IO over 20-60 min q8 (max 15 mg/kg/day or 2.2 g /day)
Ampicillin*	200-400 mg/kg/day÷q6h IV (max 12g/day)
Ampicillin/Sulbactam	(dosed as ampicillin) 200 mg/kg/day÷q6h (max 8 g/day)
Antithrombin-3	**AT3 dose = ([Goal-Current AT3 level](Weight)/1.4)**
Atropine	0.02 mg/kg/dose IV/IO (min 0.1 mg/dose, max 1 mg/dose), may repeat x1 prn, *ET*: 0.04-0.06 mg/kg/dose ET (follow by 5 mL NS flush) **INTOX** (organophos) 0.02-0.05/kg/dose IV q20min PRN (anticholinergic effects)
Ca CHLORIDE	10% (100 mg/mL): 0.2 mL/kg =20 mg/kg *central* IV (max 2 g), dilute, give slowly
Ca GLUCONATE	10% (100 mg/mL) 0.6 mL/kg =60 mg/kg IV (max 3 g), dilute
Carnitine	100 mg/kg/day divided BID IV
Cefazolin***	50-150 mg/kg/day÷q8h IV (usual adult 2 g/dose, max 12 g/day)
Cefepime**	150-200 mg/kg/day÷q8h IV (max 6 g/day)
Cefotaxime*	150-300 mg/kg/day÷q6h IV (max 12 g/day)
Ceftazidime**	150 mg/kg/day÷q8h IV (max 6 g/day)
Ceftriaxone	50-100 mg/kg/day÷q12-24h IV/IM (max 4 g/day)
Chlorothiazide	2-8 mg/kg/day÷q12h IV (max 20-40 mg/kg/day) 20-40 mg/kg/day÷q12h PO (2 g/d)
Chlorpromazine	Anxiety: 0.55 mg/kg PO (max 50), IM (max 25); Delirium: 2.5 to 6 mg/kg/day ÷q6hr
Ciprofloxacin*	20-30 mg/kg/day÷q12h IV (max 800-1200 mg/day)
Cisatracurium	0.1 mg/kg/dose IV (Liver / Renal Failure)
Clindamycin	25-40 mg/kg/day÷q8h IV (max 4.8 g/day) 10-30 mg/kg/day÷q8h PO (max 1.8 g/day)
Clonidine	*CI*: 0.5-1 mCg/kg/h IV, *PO*: 1-2 mCg/kg/dose q4h PO; *Transdermal*: 100-300 mCg/dose/day TD (7-day patch,) *Epidural*: 0.5(-2) mcg/kg/h ED (max 30 mCg/h)
Codeine*	0.5-1 mg/kg/dose PO q3-4h prn (max 60 mg/dose)
Cosyntropin	(max: 250 mcg) Cortisol levels before, 30 & 60 min

DDAVP	DI: (max 4 mcg q8hr) Platelet dysfunction: 0.3 mcg/kg q24hr
Dexamethasone	**Croup: 0.6 mg/kg/dose IM/PO x1 (max 10 mg/dose);** Inflammation: 0.5-2 mg/kg/day÷q6-8h IV/PO
Dexmedetomidine	0.5-2 mCg/kg/dose x1 over 10 min, then 0.2-2 mCg/kg/h (max 2mCg/kg/h)
Dextrose	0.5-1 g/kg IV/IO (D50W 1-2 mL/kg, D25W 2-4 mL/kg, D10W 5-10 mL/kg)
Diazepam rectal gel (Diastat)	<5 yr: 0.5 mg/kg/dose PR q2h prn, 6-11 yr: 0.3 mg/kg/dose PR q2h prn, ≥12 yr: 0.2 mg/kg/dose PR q2h prn OR: 0.05-0.2 mg/kg/dose IV q2-4h prn (max 10 mg/dose) or 0.1-0.8 mg/kg/day÷q6-8h PO (max 10mg/dose)
Digoxin	Loading dose: 8 to 50 mcg/kg IV or 10 to 60 mcg/kg PO Maintenance dosing: 2 to 12 mcg/kg IV or 2.5 to 15 mcg/kg PO
Diltiazem	1.5 to 2 mg/kg/day divided q6 to q8 PO (max 4 mg/kg/day or 480 mg/day) 0.25 mg/kg IV loading bolus, CI: 0.05 to 0.15 mg/kg/hr
Diphenhydramine	5 mg/kg/day÷q6h IV/PO (max 25-50 mg/dose)
Dobutamine	2-20 mCg/kg/min (PIV OK, CVL preferred)
Dopamine	2-20 mCg/kg/min (preferably) *central* IV
Enoxaparin*	(check Factor Xa levels 4h after) DVT/PE Treatmt: 1(-1.5) mg/kg/dose SC q12h Prophylaxis: 0.5(-0.75) mg/kg/dose SC q12h (infants <2 months: higher dose)
Epinephrine	**ANAPHYLAXIS**: *IM*: (1:1000,1mg/mL) 0.01 mg/kg/dose = 0.01 mL/kg/dose IM, max 0.5 mL/dose IM); **EpiPen:** 0.1 mg: 7.5-13 kg, 0.15 mg: 13-25 kg, 0.3 mg: >25 kg **BRONCHOSPASM**: *SQ*: (1:1,000, 1mg/mL) 0.01 mg/kg/dose = 0.01 mL/kg/dose SC q20min x 3, max 0.5 mL/dose) **ARRHYTHMIA/ARREST**: *IV*: (1:10,000, 0.1 mg/mL): 0.01 mg/kg/dose = 0.1 mL/kg/dose IV/IO q3-5min, *ET*: (1:1,000, 1 mg/mL): 0.1 mg/kg/dose = 0.1 mL/kg/dose IV/IO q3-5min **HYPOTENSION/SHOCK**: *IV*: (1:10,000, 0.1 mg/mL): 0.05-1 mCg/kg/min (preferably) *central* IV
Esmolol	500 mCg/kg IVP then 50-200 mCg/kg/min, titrate by 50 mCg/kg/min q5min
Ethacrynic Acid	IV: 1-2 mg/kg/dose q12 to 24 (idiosyncratic irreversible ototoxicity)
Etomidate	0.3 mg/kg/dose IV (Max 20 mg, consider steroids)
Famotidine**	<3mo: 0.25-0.5 mg/kg/dose q24h IV; ≥3mo: 0.6-0.8 mg/kg/day÷q12h IV (max 40 mg/day); 0.5-1 mg/kg/day÷q12-24h PO (max 40 mg/day)
Fentanyl	**ANALGESIA**: 1-2 mCg/kg/dose IV q1h prn (usual adult100 mCg/dose) may repeat ½ dose prn; *Intranasal*: 1-2 mCg/kg IN (max 50 mCg/dose) **INTUBATION: 5-10 mCg/kg/dose x1 IV/IM** **CONTINUOUS ANALGESIA**: 0.5-3 mCg/kg/h IV
Fluconazole**	3-12 mg/kg/day÷q24 IV/PO (max 800 mg/day)
Flumazenil	0.01 mg/kg/dose IV x1 may repeat prn (max 0.2 mg/kg/dose, total max 0.05 mg/kg or 1 mg)
Fomepizole	15 mg/kg/dose IV load, then 10 mg/kg IV q12h (if on HD give 15 mg/kg/dose q12h IV)
Fosphenytoin	20 mg PE/kg IV load (run at 3 mg PE/kg/min, max 150 mg PE/min), then 5-8 mg PE/kg/day÷q12h IV/IM (trough: total 10-20 mCg/mL, free: 0.4-1.4 mCg/mL)
Furosemide*	0.5-1 mg/kg/dose q6h IV/PO prn (usual adult 20 mg/dose); *CI*: 0.05-0.1 mg/kg/h
Gentamycin** (trough before 3rd dose)	Newborn: 4 mg/kg/day÷q24h IV 1mo-10yr: 7.5 mg/kg/day÷q8-24 IV >10yr: 6 mg/kg/day÷q8-24h IV

Glucagon	0.02-0.05 mg/kg (max 1mg anaphylaxis and 10mg Ca channel OD) load 0.05-0.1 mCg/kg/hr (max 5 mg/hr)
Glycopyrrolate	4-10 mCg/kg/dose q4-8h IV (max 0.2 mg/dose); *PO*: 40-100 mCg/kg/dose q4-8h PO prn (max 2 mg/dose); REVERSAL: 0.2 mg/1 mg neostigmine used IV
Haloperidol	0.025-0.075 mg/kg/dose (max 5 mg/dose 10 mg/dose if PO) PO/IM/IV (long QT)
Heparin	75 units/kg IV x1 over 10 min, then <1yr: 28 units/kg/h IV ≥1yr: 20 units/kg/h IV (obtain aPTT after 4h; goal: 60-85 sec, titrate by 10-15% q4h until therapeutic)
Hydralazine	0.1-0.5 mg/kg/dose IV q4-6h (max 20 mg/dose; 1.7-3.5 mg/kg/day); 0.75-1 mg/kg/day÷q6-12h PO (max 25 mg/dose titrated up to 200 mg/dose)
Hydrocortisone	**MAINTENANCE (CAH / AI):** 12.5 mg/m^2/day÷q8h PO **STRESS DOSE**: 50-100 mg/m^2/day÷q3-6h IV/IM or CI; *PO*: 50-75 mg/m^2/day÷q6-8h **ACUTE ADRENAL CRISIS: 50 mg/m^2 IV load then 50 mg/m^2/day as CI or q6h IV** **IMMUNE SUPPRESSION**: 1-5 mg/kg/day÷q12-24h IV/IM or 2.5-10 mg/kg/day÷q6-8h PO (max 250mg/dose); **ANAPHYLAXIS/ADRENAL INSUF.**: 1-2 mg/kg/dose (max 100 mg/dose)
Hydromorphone	0.015 mg/kg/dose IV q2-3h prn (max 1-2 mg/dose), 0.03-0.08 mg/kg/dose PO q4-6h prn (max 4 mg/dose)
Hyper. Saline 3%	**0.5-2 mL/kg IV over 15 min x 1; then *CI*: 1-2 mL/kg/h (preferably) *central* IV**
Ibuprofen	10 mg/kg/dose PO q6h prn (usual adult 600 mg/dose)
Insulin (regular)	0.05-0.1 units/kg/h IV
Ipratropium	<10kg: 0.25 mg, >10kg: 0.5 mg INH q20min with albuterol, then q6h x 24h
Isoproterenol	CI: 0.01-0.5 mcg/kg/min
Isradipine	0.15-0.2 mg/kg/day÷q6-8h PO, titrate up to 0.8 mg/kg/day (max 20 mg/day)
Kayexalate	1 g/kg/dose q6h PO (max 15 g/dose) or1 g/kg/dose q2-6h PR (max 50 g/dose) (exchange ratio: 1 mEq K per 1 g resin)
Ketamine	**SEDATION**: 0.5-2 mg/kg/dose IV x1 over 1 min (max 100 mg/dose), repeat 0.5 mg/kg/dose (max 50 mg/dose) q5-10 min (max total dose 5 mg/kg or 500 mg); 3-5 mg/kg/dose IM x1; 5 mg/kg/dose PO x1 **INDUCTION**: 3-5 mg/kg/dose IV/IM x1; *CI*: 0.01-0.03 mg/kg/min IV, titrate by 50% q10m
Ketorolac	0.5 mg/kg/dose IV/IM q6h (max 30 mg/dose)
Labetolol	0.2-1 mg/kg/dose IV q10min (max 20 mg/dose); *CI*: 0.4-1 mg/kg/h (max 3 mg/kg/h)
Lansoprazole	<30kg: 15 mg/dose q24h PO/IV; ≥30 kg: 30 mg/dose q12-24h PO/IV
Levetiracetam	20-40 mg/kg/day÷q12h PO/IV (max 30 mg/kg/dose or 2,000 mg/dose) May load 30 to 40 mg/kg (Max 3,000 mg IV/PO) for status epilepticus
Lidocaine	0.5-1 mg/kg/dose IV/IO x1-2 q15min prn; *CI*: 20-50 mCg/kg/min IV/IO; *ET*: 2-5 × IVdose
Lorazepam	0.05-0.1 mg/kg/dose IV/PO q4-8h prn, may repeat 0.05 mg/kg/dose in 10-15 min (max 2-4 mg/dose); *CI*: 0.05-0.15 mg/kg/h IV; ANTIEMETIC: 0.01-0.05 mg/kg/dose IV/PO q6h (max 2 mg/dose)
Magnesium Sulfate	**ASTHMA**: 25-50 mg/kg/dose IV over 20 min (max 2 g/dose), **Infusion (asthma)** **Hypomagnesemia**: 25-50 mg/kg/dose q4-6h IV over 2h, **CI: 25 mg/kg/hr** **TORSADES:** 25-50 mg/kg/dose IV bolus over 5 min **Goal Mg = 4**
Mannitol	**0.5-1 g/kg/dose IV over 20 min then 0.25-0.5 g/kg/dose IV q4-6hr; max: 50g**
Methylprednisolone	2 mg/kg/dose IV x1, then 2-4 mg/kg/day÷q6-12h IV (max 60 mg/dose)
Methadone	PO/IM/IV: 0.1 mg/kg/dose q4 to 12 (max 10 mg/dose)
Metolazone	PO 0.1-0.2 mg/kg/dose q12 to 24
Metoprolol	PO: 1 to 2 mg/kg/day divided q12 (max 6 mg/kg/day or 200 mg/day)

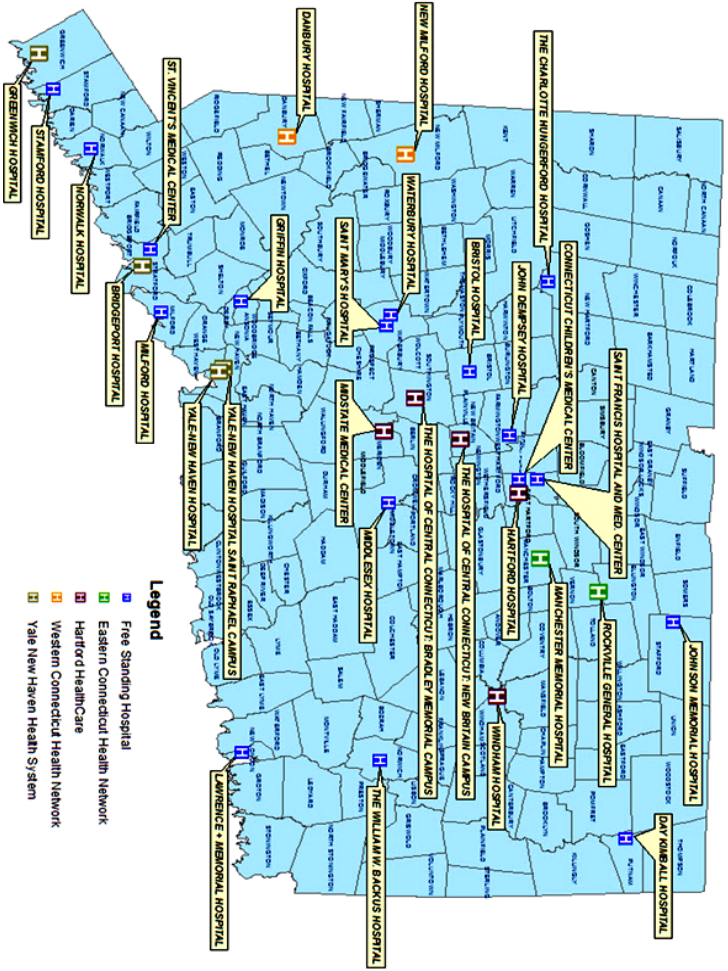
Metronidazole*	30 mg/kg/day÷q6h IV/PO (max 4 g/day)
Midazolam*	0.05-0.1 mg/kg/dose IV/IM q1-2h prn (max 2 mg/dose IV); *PO*: 0.25-0.75 mg/kg/dose PO x1 (max 15-20 mg/dose PO); *IN*: 0.5 mg/kg/dose IN; *CI*: 0.05-0.15 mg/kg/h
Milrinone**	CPB: 50-75 mCg/kg/dose IV x1 over 15 min, followed by 3 mcg/kg/min IV x 30 min, then *CI*: 0.25-0.75 mCg/kg/min IV
Morphine*	0.05-0.1 mg/kg/dose q2-4h IV prn (adult 10 mg/dose), *CI*: 0.025-0.1 mg/kg/h IV
N-acetylcysteine	140 mg/kg/dose PO x1, then 70 mg/kg/dose PO q4h x 17 doses or *IV*: 150 mg/kg/dose x1 in D5W over 1h IV, then 50 mg/kg/dose in D5W over 4h, then 10 mg/kg/dose in D5W over 16h IV
Naloxone	**FULL REVERSAL**: 0.1 mg/kg/dose = 100 mCg/kg IV/IM/ET (max 2 mg/dose) q2min prn; **PARTIAL REVERSAL** 0.001-0.01 mg/kg/dose = 1-10 mCg/kg IV/IM q2min prn, *Maintenance*: 0.002-0.16 mg/kg/h = 2-160 mCg/kg/h IV/IO
Neostigmine*	0.04-0.08 mg/kg/dose IV (max 5 mg), premed with glycopyrrolate 5-15 mCg/kg/dose IV (~0.2 mg glycopyrrolate for every 1 mg neostigmine)
Nicardipine	**0.5-1 mCg/kg/min IV, titrate q15min (max 5 mCg/kg/min)**
Nifedipine	0.25-0.5 mg/kg/dose q4-6h PO/SL prn (max 10 mg/dose); HCM: 0.6-0.9 mg/kg/day÷q6-8h PO/SL
Nitroglycerin	0.25-5 mCg/kg/min IV increase q5min prn (max 10 mCg/kg/min or 200 mCg/min)
Nitroprusside	0.05-10 mCg/kg/min IV (cyanide & thiocyanate levels if >4mCg/kg/min or >3 days)
Norepinephrine	**WARM SHOCK (low SVR) 0.05-1 mCg/kg/min IV (max 2 mCg/kg/min)**
Octreotide	1-2 mCg/kg/h IV (max 50 mCg/h)
Ondansetron	0.1-0.15 mg/kg/dose q8h IV/IM prn (max 4 mg/dose); *PO*: <1yr: 2 mg/dose, 1-12yr: 4 mg/dose, >12yr: 8 mg/dose q8h PO prn
Oxacillin*	150-200 mg/kg/day÷q4-6h IV (max 12 g/day)
Oxycodone	0.05-0.15 mg/kg/dose PO q4-6h prn (typical adult 5-10 mg/dose) ± acetaminophen
Penicillin G*	*IV*: 100K-200K units/kg/day÷q4-6h IV (max 24 Million units/day)
Penicillin G Benz.	*IM*: 50K units/kg IM x1 (max 1.2 Million units/dose)
Pentobarbital	**SEDATION** 1-3 mg/kg/dose IV q5min prn (max 150 mg/dose); 2-6 mg/kg/dose IM/PO **SEIZURES** 10-15 mg/kg/dose IV until burst suppression, then *CI*: 1 mg/kg/h for maint.
Phenobarbital*	20 mg/kg/dose IV load, then 5 mg/kg/day÷q12-24h IV/PO (trough: 15-40 mCg/mL)
Phenylephrine	**5-20 mCg/kg/dose IV bolus q15min prn, *CI*: 0.1-0.5 mCg/kg/min; *IM/SC*: 0.1 mCg/kg/dose IM/SC q1-2h prn (max 5 mg/dose)**
Phytonadione (K)	1-5 mg/dose IM/SC/IV/PO q24h x 3 days (max 25 mg PO, 10 mg IV)
Piperacillin/Tazobactam	(dosed as piperacillin) 300 mg/kg/day÷q6h IV (max 18 g/day)
Pralidoxime	Most effective immediately at exposure: 20-50 mg/kg (max 2g) load, 10-20 mg/kg q6 IV
Prednisone/ Prednisolone	**ASTHMA:** 2 mg/kg/dose PO x1 (max 60 mg/dose), then 2 mg/kg/day÷q12h PO
Procainamide*	<1yr: 3-7 mg/kg/dose IV/IO load over 30 min, then 20-80 mCg/kg/min IV ≥1yr: 5-15 mg/kg/dose IV/IO load over 30 min, then 20-80 mCg/kg/min IV (max 100 mg/dose, 2 g/day)
Propofol	**CONSCIOUS SEDATION: 1-2 mg/kg/dose IV (max 100 mg/dose) q10-15min; INDUCTION**: 2-3 mg/kg/dose IV; *CI*: 25-250 mCg/kg/min IV
Protamine Sulfate	1 mg per 100U heparin if <30 min, 05-0.75 mg per 100U heparin if 30-60 min, 0.375 to 0.5 mg per 100U hep. if 60-120 min, 0.25 mg per 100U hep if >120 min
Prostaglandin E1	(see alprostadil)

Racemic Epi 2.25%	<5kg: 0.25 mL, , ≥5kg: 0.5 mL INH q15min × 4 doses, then q1h PRN
Ranitidine**	3 mg/kg/day÷q8h IV (max 60 mg/dose) or 4-6 mg/kg/day÷q12h PO (max 150 mg/dose)
Rocuronium	0.6-1.2 mg/kg/dose IV x1
Sildenafil	0.5 to 2.5 mg/kg/dose q6 to q12
Sodium Bicarb (1 mEq/mL)	1-2 mEq/kg = 1-2 mL/kg IV/IO, (*calculation*: 0.3 × wt × Base Deficit), **ALKALIZATION:** 150 mEq $NaHCO_3$/L D5W at 1M
Sotolal	PO (>2 y/o): 30 mg/m^2/dose q8hr OR 2 mg/kg/day divided q8hr If less than 2 y/o see dose adjusting nomogram (less than 30 mg/m^2/day)
Spironolactone*	1-3 mg/kg/day÷q6-24h PO (max 200 mg/day)
Succinylcholine	**1-2 mg/kg/dose IV (max 150 mg), 3-4 mg/kg/dose IM**
Terbutaline**	Loading dose: 10 mCg/kg/dose IV/SC prn q15min until *CI*: 0.2-10 mCg/kg/min IV (max 20 mg/h)
Thiopental***	**INCREASED ICP: 1.5-5 mg/kg/dose IV** **INDUCTION**: 4-6 mg/kg/dose IV (max 280 mg/dose)
Tobramycin***	7.5 mg/kg/day÷q8h IV/IM; CF: 10-12 mg/kg/day÷q24h IV; *NEB*: 300 mg/dose q12h INH
tPA (Alteplase)	**CATHETER CLEARANCE**: Catheter Volume + 10% (max 2 mg/2 mL) in port for 2-4h; **SYSTEMIC THROMBOLYSIS**: 0.1-0.6 mg/kg/h IV x 6h (expect heme in urine!)
Tranexamic acid	**IV Load:** 10 to 30 mg/kg (max 100 mg/kg or 1g) over 15 min (max 100mg/min) followed by **infusion** at 5 to 10 mg/kg/hour. May be nebulized for alveolar hemorrhage 250 mg q6 for <25kg, 500 mg q6 for >25 kg
Valproic Acid	5-20 mg/kg/dose IV bolus, then 15-30 mg/kg/day÷Q8-12h PO or 15-30 mg/kg/day÷Q6h IV (max 1 g/day; level: 50-150 mg/L)
Vancomycin***	40-60 mg/kg/day÷q6-8h (max 2 g/day), Typically 15 mg/kg/dose IV, trough: 5-15, 15-20 for CNS infections
Vasopressin	**DI:** 0.5 ***milliunits/kg/h*** IV, double dose q30min prn to effect (UOP <2 mL/kg/h)(max 10 mU/kg/h); (Check Units!) **GI BLEED**: bolus 300 mU/kg IV x1, then 2-5 ***mU/kg/min*** IV, titrate to effect up to 10 mU/kg/min IV for 12-24h, then taper over 24-48h; **Pulseless VF/VT/CARDIAC ARREST**: 400 mU/kg IV x1 (max 40 units); **SHOCK**: 2-3 ***mU/kg/min*** IV (max 40 mU/min)
Vecuronium	0.1-0.3 mg/kg/dose IV x1, then 0.1 mg/kg/dose q1h prn or *CI*: 0.05-0.2 mg/kg/h IV

Characteristic	Description	Symbol	Formula
Dose	Loading or maintenance	**D**	
Volume of distribution	Volume in which drug is distributed	**V_d**	$V_d=D/C_0$
Concentration	Amount of drug in a given volume of plasma	**C_0**	$C_0=D/V_d$
Elimination half life	Time required for drug to reach half its original value	**$t_{1/2}$**	$T_{1/2}=0.693/k_e$
Elimination constant	Rate at which drug is removed from body	**k_e**	$k_e=0.693/t_{1/2}$
Clearance	Volume of plasma cleared of drug per time	**CL**	$CL=(V_d)(k_e)$
Bioavailability	Systemically available fraction of drug	**f**	$f=(AUC_{PO})(D_{IV})/(AUC_{IV})(D_{PO})$
Therapeutic Index	Ratio of effective to lethal doses	**TI**	$TI=LD_{50}/ED_{50}$

Hospital	Transport time (one-way)	
	Air (Helipad?)	Ground
Backus	25 min (Y)	60 min
Boston Children's (MA)	50 min (Y)	180 min
Bridgeport	20 min (Y)	30 min
Charlotte-Hungerford	20 min (Y)	60 min
Columbia (NYC)	40 min (N, 15 min)	120 min
CCMC	15 min (Y)	50 min
Danbury	20 min (Y)	60 min
Greenwich	30 min (N)	50 min
Griffin	15 min (N)	25 min
Hasbro (RI)	40 min (Y)	135 min
Hosp. Special Care	15 min (Y)	40 min
Lawrence & Memorial	20 min (Y)	60 min
Mid State Med Cntr	10 min (Y)	30 min
Middlesex	10 min (Y)	45 min
Milford	10 min (N, 5 min)	25 min
Norwalk	15 min (Y)	45 min
Pequot	25 min (N, 5 min)	65 min
St. Mary's	10 min (Y)	45 min
St. Raphael's	2 min (Y)	5 min
St. Vincent's	10 min (Y)	35 min
Shriner's Burn Cntr (MA)	50 min (Y)	180 min
Shoreline	10 min (Y)	35 min
Stamford	15 min (N, 5 min)	55 min
Waterbury	10 min (N, 2 min)	40 min

Y-Access: 1-888-964-4233, Yale Pedi Unit: 203-688-3333
Yale PICU: 203-688-2323, PICU FAX 203-688-1617



Card Index

Airway	Light Blue	1-5
Respiratory	Dark Blue	6-14
Cardiology	Red	14-36
Sedation	Purple	36-37
GI/FEN	Brown	38-43
Neurology	Pink	44-47
Immuno/Heme	Gold	48-52
Pharmacology	Grey	53-57

EZ-IO	
kg	mm
< 3	15
3-39	25
> 40	45

Age	Wt(kg)/BSA(m^2)	HR	SBP	RR	ETT	Blade	LMA
PTNB	Variable	120-180	40-60	55-65	2.5-3.0	0	N/A
TNB	3.5 / 0.25	90-170	50-90	40-60	3.0-3.5	1	1
1 m/o	4 / 0.27	110-180	66-104	30-50	3.5-4.0	1	1
6 m/o	7 / 0.38	110-180	72-110	20-30	3.5-4.0	1	1
1 y/o	10 / 0.49	80-160	72-110	20-30	4.0-4.5	1.5	1.5
2 y/o	13 / 0.56	80-130	72-110	20-30	4.0-4.5	2	1.5-2
4 y/o	17 / 0.74	80-120	74-112	20-30	5.0-5.5	2	2
6 y/o	22 / 0.86	75-115	77-115	18-24	5.0-5.5	2	2-2.5
8 y/o	26 / 1.0	70-110	80-118	18-22	6.0	2	2.5
10 y/o	35 / 1.23	70-110	84-121	16-20	6.0-6.5	2-3	3
12 y/o	45 / 1.36	60-110	88-126	16-20	7	2-3	4
14 y/o	50+	60-105	92-130	16-20	7.0-7.5	3	5
Adult	70 / 1.73	60-100	95-130	12-18	7-8	3	1.5-2

Age	Central line	Chest tube	Foley	NG	Suction	ETT distance to gum
1-6 m/o	4-5	10-12	6	8	8	9-10
1 y/o	4-5	16-20	8	10	8	12
2 y/o	5	18-20	8	10	8	14
4 y/o	5	18-22	10	12	10	15
6 y/o	5	20-22	10	12	10	15
8 y/o	5-7	20-24	12	14	10	18
10 y/o	7	24-34	12	16	12	18
12 y/o	7	24-34	12	16	12	20
Adult	7	24-34	14-18	18	12-14	20-22

ETT size: (age in years)/4 + 4 ETT Distance to gum: (ETT) x (3) D in (mm) = F/3