Acute Respiratory Failure

Objectives for pre-Course reading

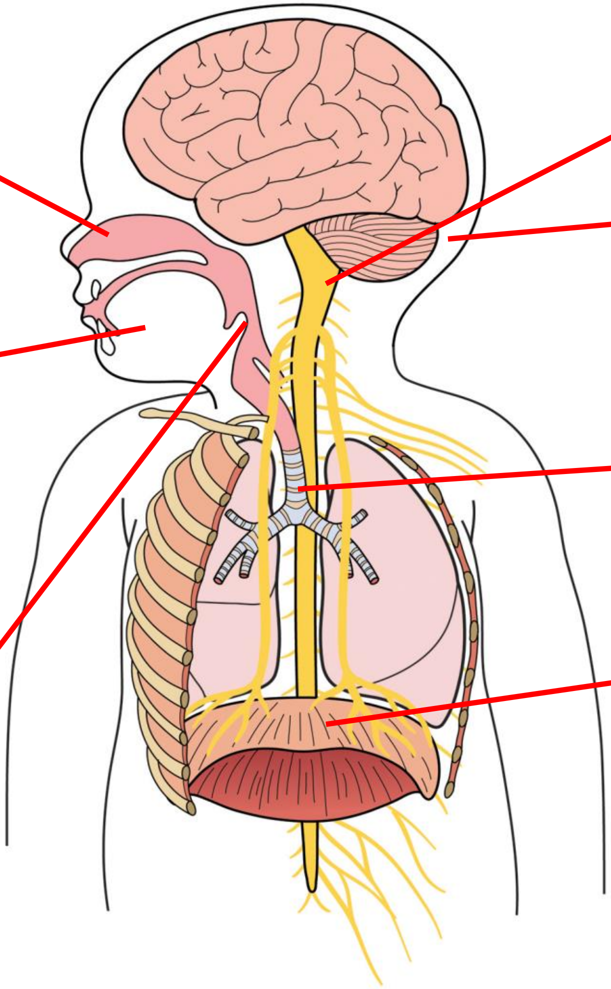
- Describe the similarities and differences between adults, children and infants' anatomy and their physiological responses to critical illness
- Identify clinical signs of respiratory distress and of impending respiratory failure in pediatric patients

Child vs adult anatomy

<u>Nasal airway precarious :</u>
Infants nasal breathers : nasal congestion can obstruct ventilation

<u>Oral airway challenging :</u>
Relatively large tongue, small oropharynx

<u>Airway instrumentation challenging :</u>
- high, anterior larynx
- large floppy epiglottis
- short, compressible trachea



Immature respiratory control

Large head, short neck, prominent occiput

Small airways, little cartilaginous support early in life

<u>Inefficient ventilatory mechanics :</u>
- horizontal ribs
- flat diaphragm
- underdevoped accessory muscles
- compliance chest >> lungs

Child vs. adult physiology

FRC / Closing volume in infants

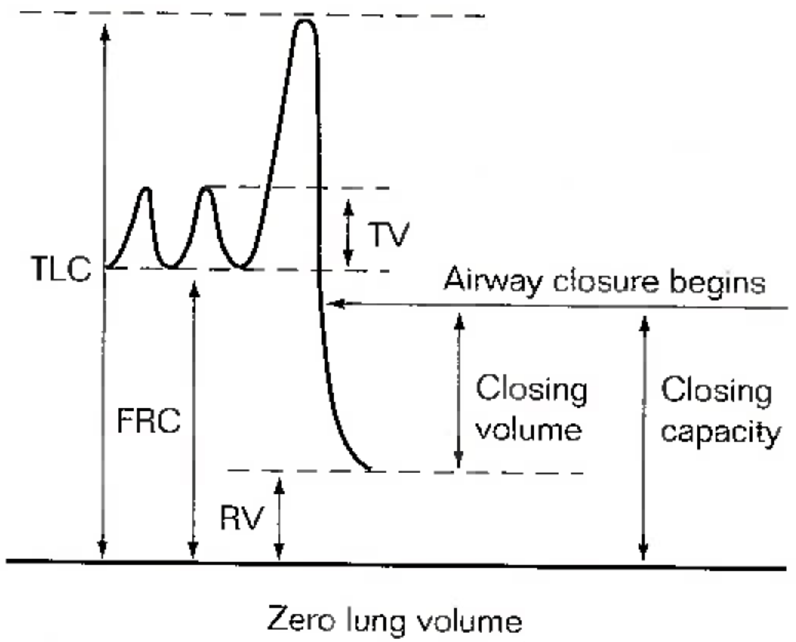
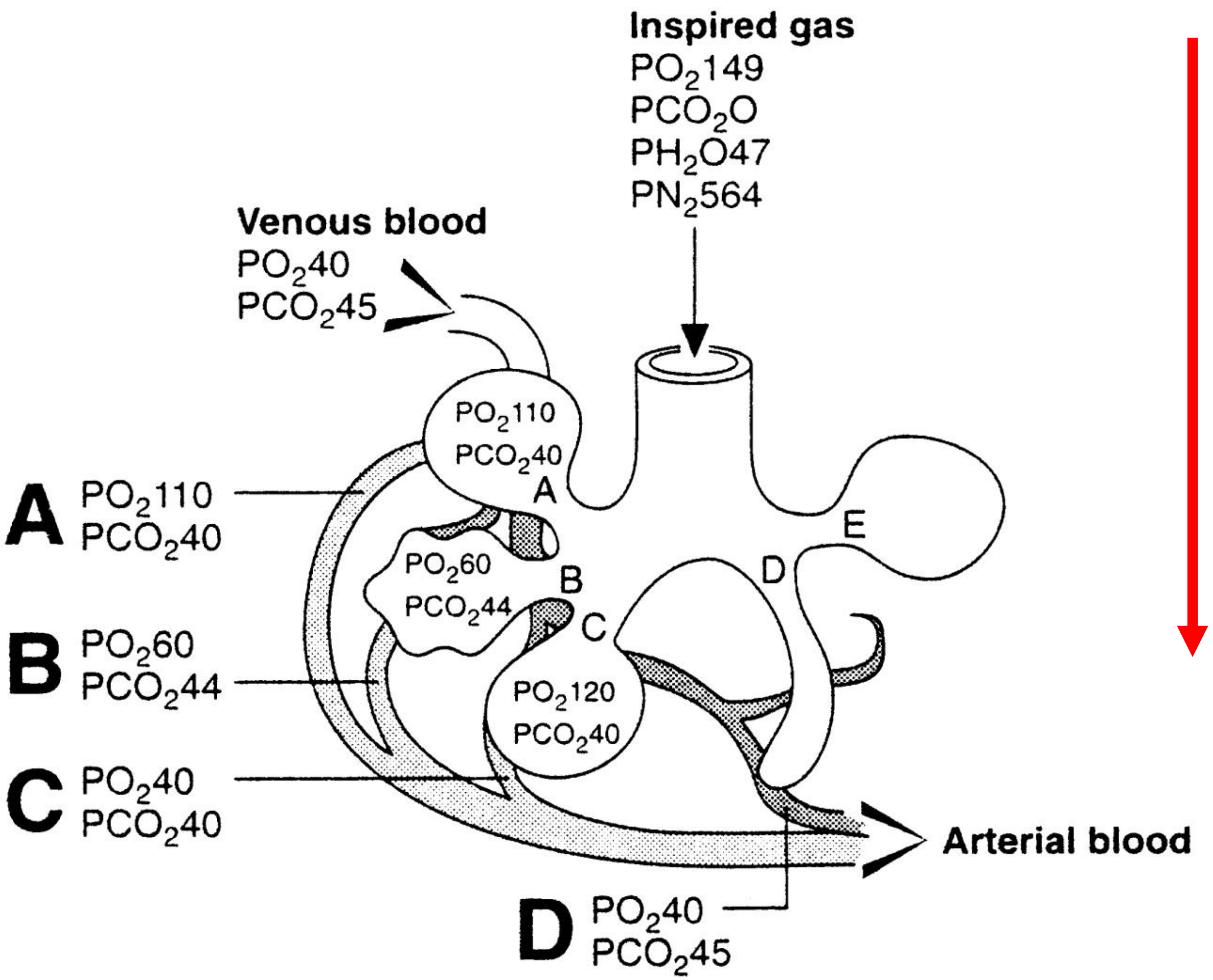


Figure 11.6 Static lung volumes and closing lung volumes. Spirogram to demonstrate normal static lung volume nomenclature. The *y* axis is volume and the *x* axis is time during two normal breaths, a maximum inspiration followed by maximal expiration. The closing volumes are included to help one to visualise how the closing volume to FRC ratio may vary as it does between children and adults. TLC – total lung capacity, FRC – functional residual capacity, RV – residual volume, TV – tidal volume. (With permission from Nunn JF 1993. *Applied Respiratory Physiology* Heinemann Educational Publishers; p. 83.)

Ventilation (V) perfusion (Q) relationships in the lung



A Normal

B VQ mismatch

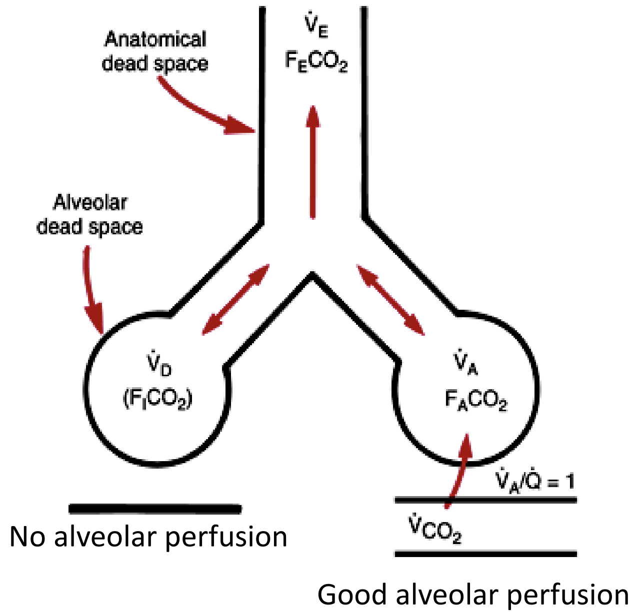
C Diffusion block

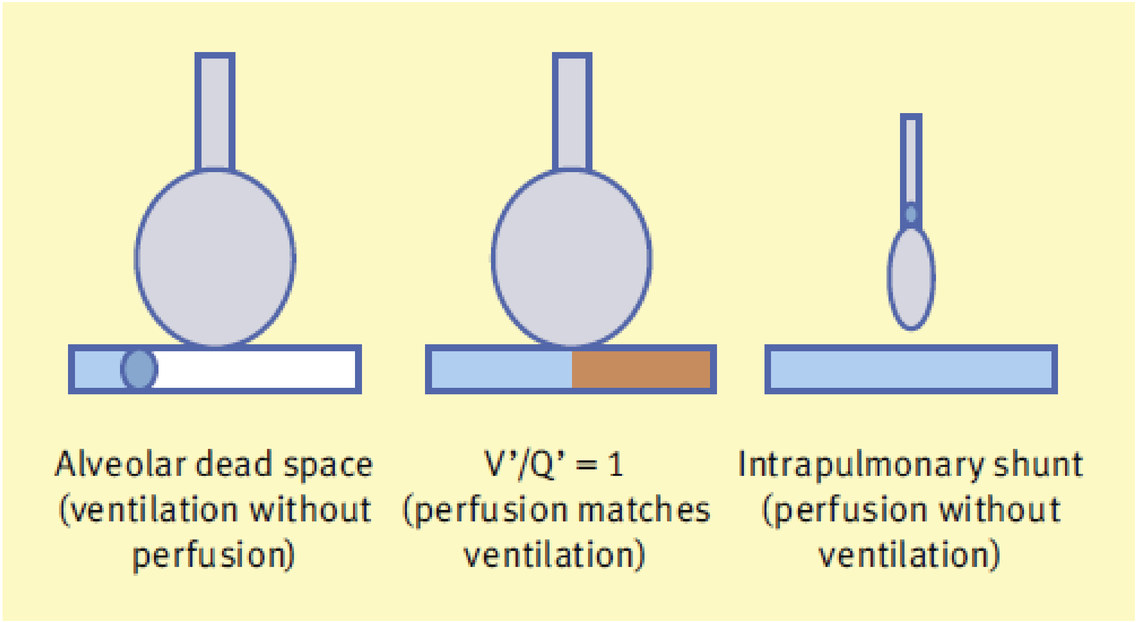
D Shunt

E Dead space

ALL of these variants of ventilation / perfusion matching may be present in the lungs in varying proportions at any time

Shunt /dead space / V/Q mismatch





V/Q > 1

V/Q < 1

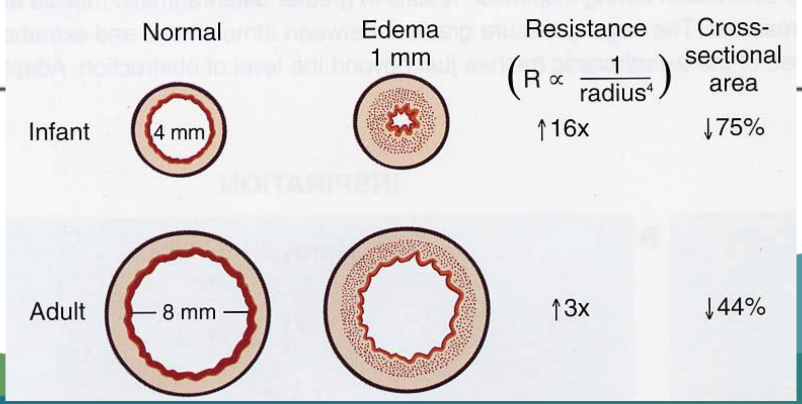
May have all present in same patient at same time (bronchiolitis, ARDS)

Child vs Adult anatomy and physiology

Table 1. Differences in Pediatric and Adult Physiology

Feature	Child	Adult
Airway cartilage formation	Incomplete	Complete
Airway resistance	Greater increase in airway resistance with reduction in airway radius	Smaller increase in airway resistance with reduction in airway radius
Chest-wall compliance	Greater compliance in view of incomplete ribcage ossification	Less compliant in view of ribcage ossification
Alveolar maturation and impact on FRC	20–300 million alveoli (age-dependent); lower FRC	300 million mature alveoli; higher FRC
Respiratory muscle reserve	More reliant on diaphragm	Less reliant on diaphragm
Risk of pulmonary vascular remodeling	Greater due to higher pulmonary vascular resistance during perinatal transition	Lower
Metabolic requirements	Higher	Lower

FRC = functional residual capacity



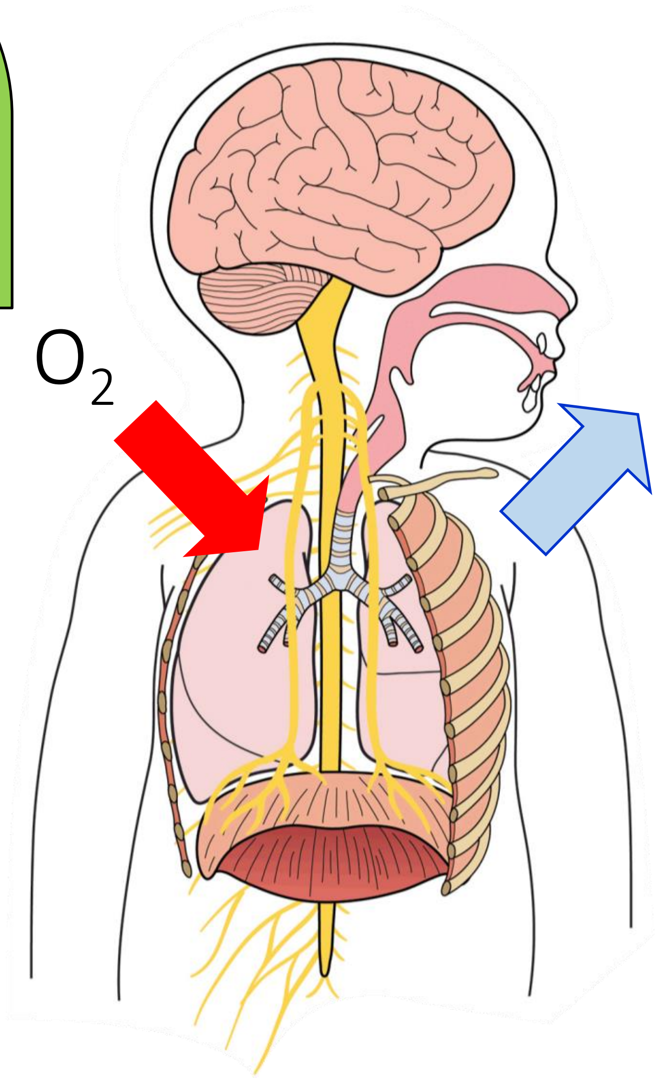
Infants and children have limited respiratory reserve and decompensate rapidly in the face of respiratory compromise………..

Let’s review the physiology to understand why

FiO_2
Alv MV
V/Q
D_LO_2

O_2

Normal ventilation



CO_2

Alv MV
(RR)
(Exh TV)

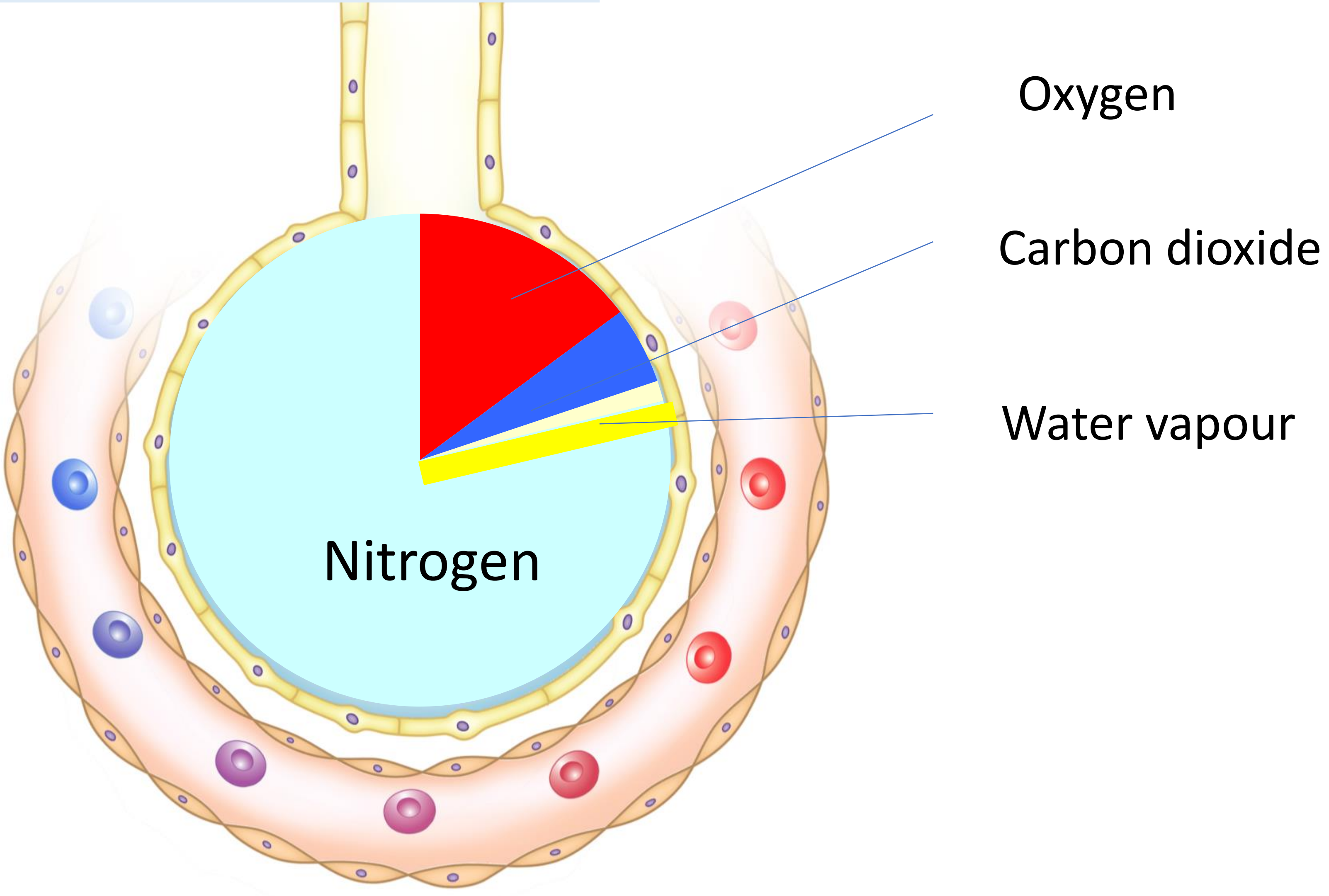
$$\text{Alv MV} = \text{RR} \times (V_T - V_{DS})$$

Carbon dioxide removal

- Largely dependent on alveolar ventilation
- Alveolar ventilation = Resp rate X exhaled tidal volume (TV)
- Exhaled TV = Total tidal volume (6-10 ml / Kg)– dead space volume (3 ml / Kg)

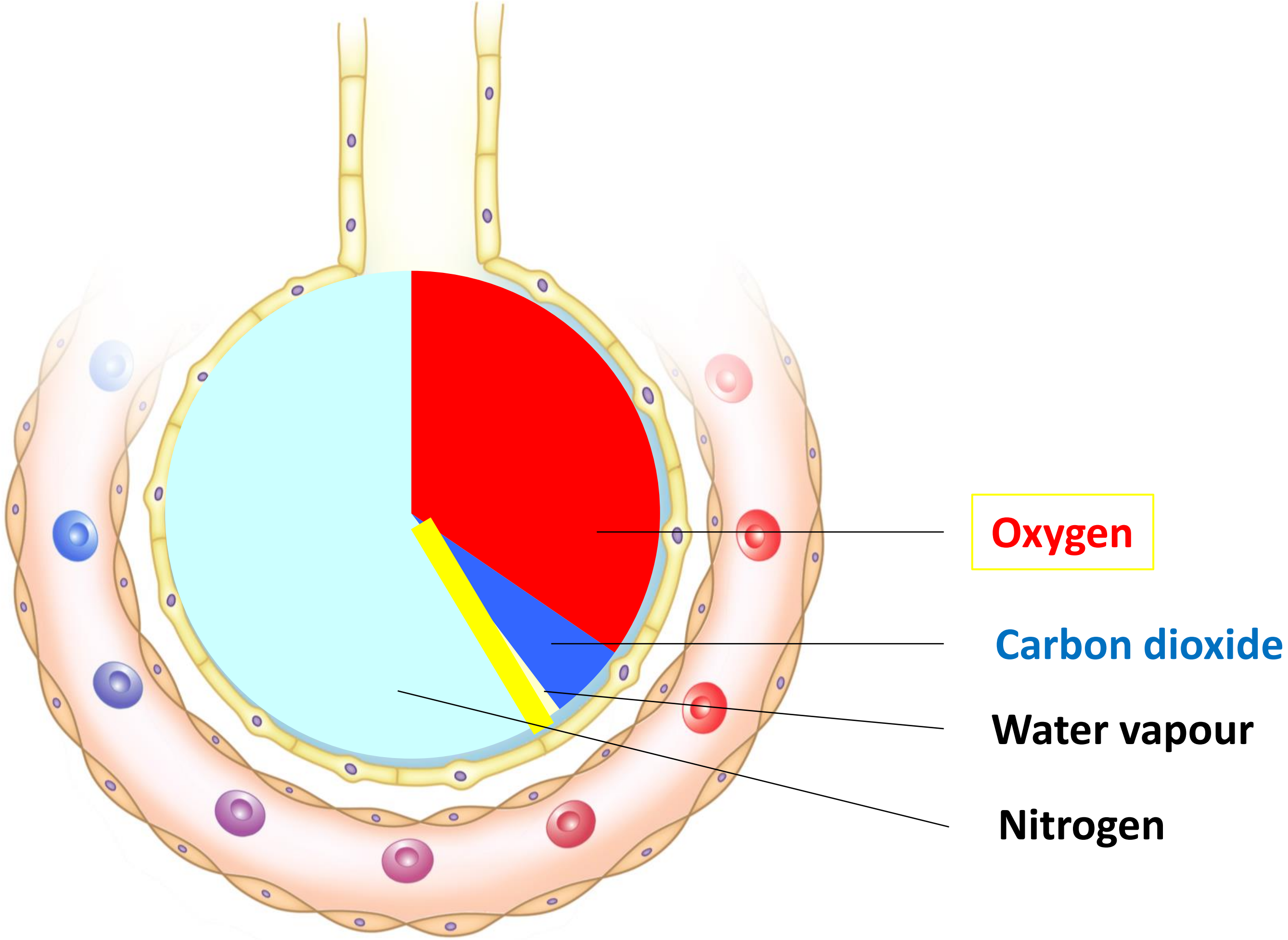
- Anatomical dead space is constant
- Physiological dead space variable dependent on VQ matching
- Equipment dead space

Normal alveolar gas mixture



Alveolar pressure $= P_AO_2 + P_ACO_2 + P_AH_2O + P_AN_2$

Alveolar gas with supplemental FiO_2



$$\text{Alveolar pressure} = P_AO_2 + P_ACO_2 + P_AH_2O + P_AN_2$$

Alveolar Gas Equation

$$P_AO_2 = [FiO_2 \times (P_{atm} - P_{H2O})] -- (P_ACO_2/RQ)$$

$PACO_2 = PaCO_2$ Resp Quotient (RQ) = 0.8

Patm = 760mmHg P_{H2O} = 47mmHG

$$P_AO_2 = FiO_2 \times (760 - 47mmHg) - P_aCO_2/0.8$$

Practical applications of the Alveolar Gas Equation

Alveolar gas equation: PAO_2= FiO_2* (Patm-PH2O) –(PaCO2/RQ)

Breathing in RA

- PaCO2= 40, FiO2 =0.21
- PAO2= 0.21 * (760-47) –(40/0.8) = 150-50 = 100 (measured sat of 100%)

Breathing 100% O_2

- P_AO_2 = 1.00 x 713 – (40/0.8) = 663mmHg (measured sat of 100%)

Rise in PaCO2 from hypoventilation, with consequent hypoxemia

- PaCO2= 80, FiO2= 0.21
- PAO2 = 0.21 (760-47) –(80/0.8) = 150-100 = 50 (measured sat approx 80%)

Hypoxemia from hypoventilation easily overcome with small amount of oxygen

- PaCO2= 80, FiO2= 0.30
- PAO2 = 0.30 (760-47) –(80/0.8) = 213-100 = 114 (measured sat of 100%)

A-a (O_2) Gradient

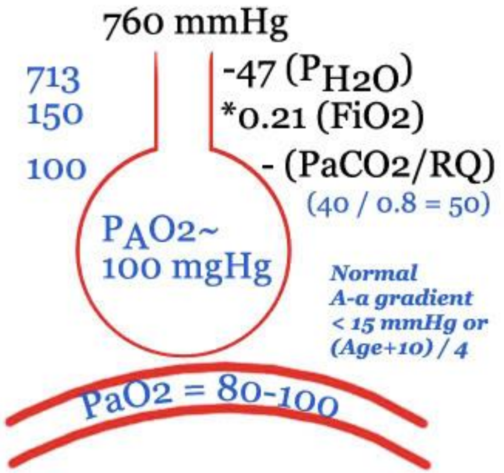
Estimate difference between alveolar partial pressure O_2 (PAO_2) and arterial PaO_2

A-a (O_2) Gradient = $PAO_2 – PaO_2$

- PAO2= (P_{atm}–P_{H2O}) x FiO2 –(PaCO2 / RQ)= (760 –47) x 0.21 –(40 / 0.8)(713 x 0.21) –50
- PAO2= 149 –50 = 99= 352 – 60 = 292
- Normal PaO2= 70 –100

Normal A –a gradient= 99 –80 = ~ 20 mm Hg (or **0 –30 mm Hg**) (or Age + 10 /4)

Example : Patient has PaO_2 60 on FiO_2 0.6 and $PaCO_2$ is 60
PAO_2 = (713*0.6) – (60/0.8) = 427-75 = 352
A-a gradient = 352 – 60 = 292



Acute Respiratory Failure

- Hypoxaemic respiratory failure:

  $PaO_2 \leq 60mmHg$ (approxmate

- Hypercarbic respiratory failure:

  $PaCO_2 \geq 50mmHg$

- Common to have features of both in respiratory failure

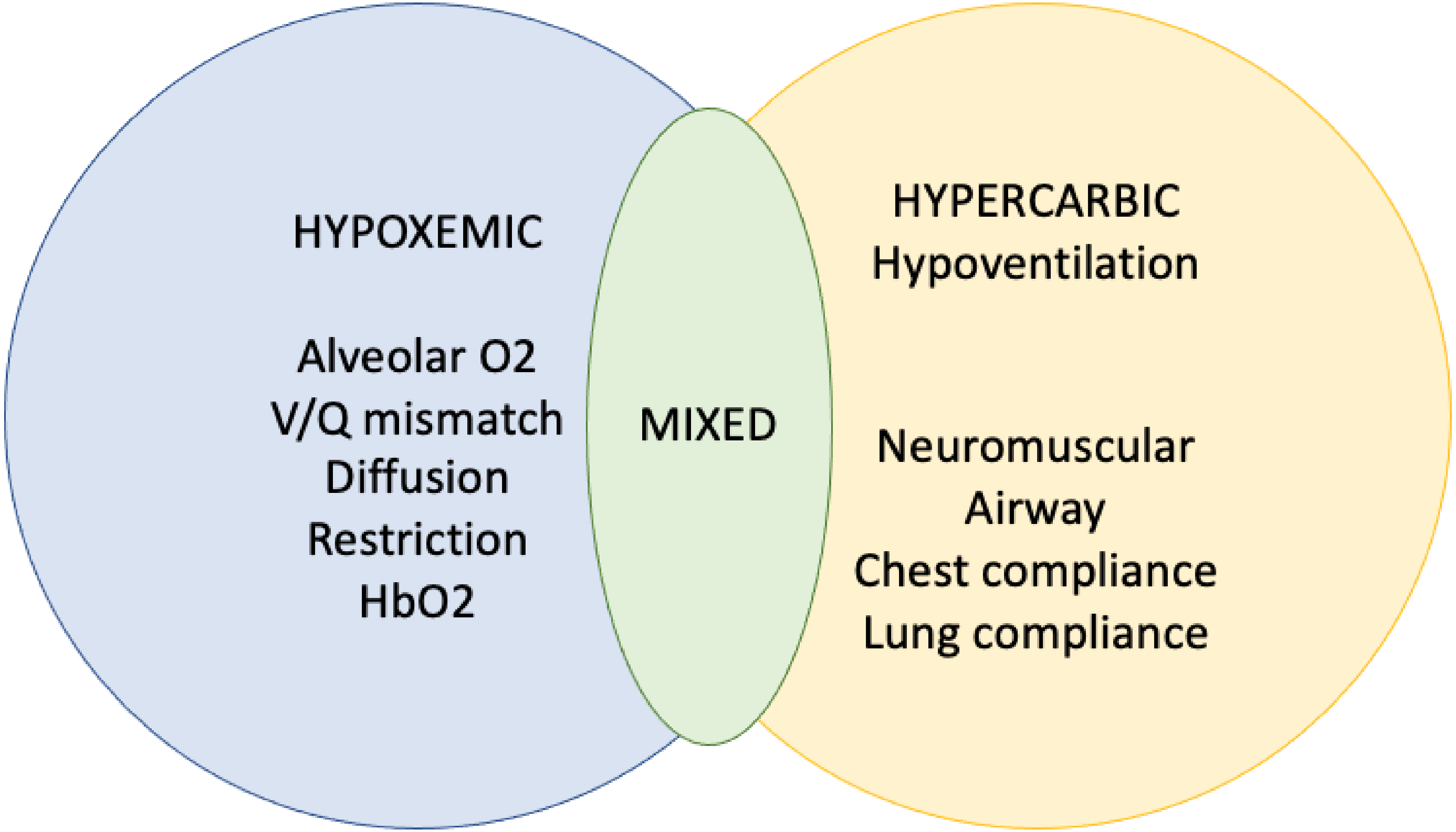
Common causes of hypoxemia

- Ventilation – perfusion mismatch
- Shunt
- Hypoventilation with high P_aCO_2
- Low inspired FiO_2 - altitude
- Alveolar diffusion abnormality – rare in children

Common causes of hypoventilation / hypercarbia

- Hypoventilation from physiological exhaustion from trying to ventilate diseased, non-compliant lungs in infants with inefficient respiratory mechanics : bronchiolitis
- Hypoventilation from CNS depression
  - CNS disease, medication, trauma, vascular
- Hypoventilation due to disease determined weakness
  - Congenital, acquired, medication
- Obstructed airway
- Chest compliance
  - Scoliosis, trauma
- Lung compliance
  - Restrictive lung disease

Types of respiratory failure



Approach to managing hypoxemic respiratory failure

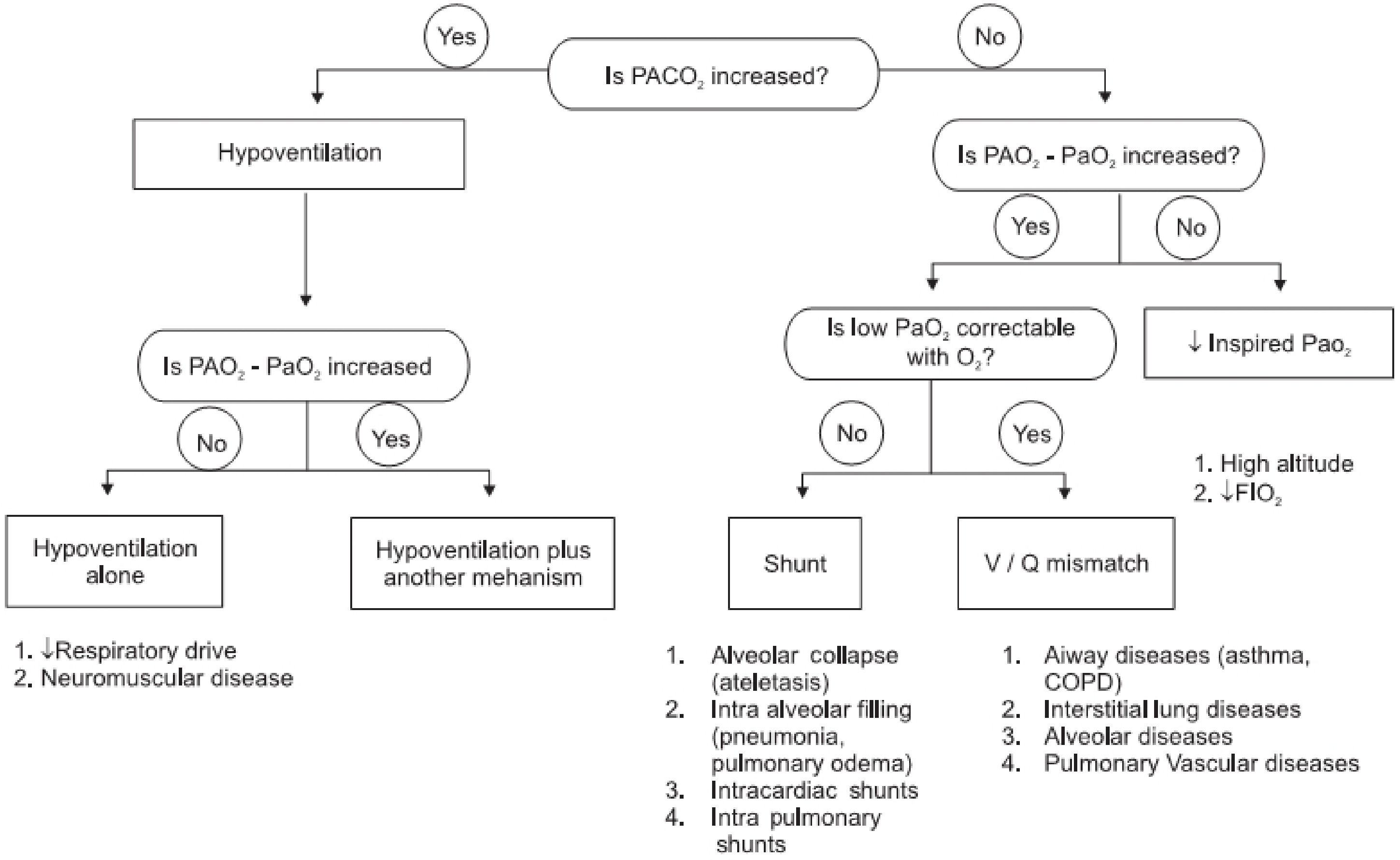
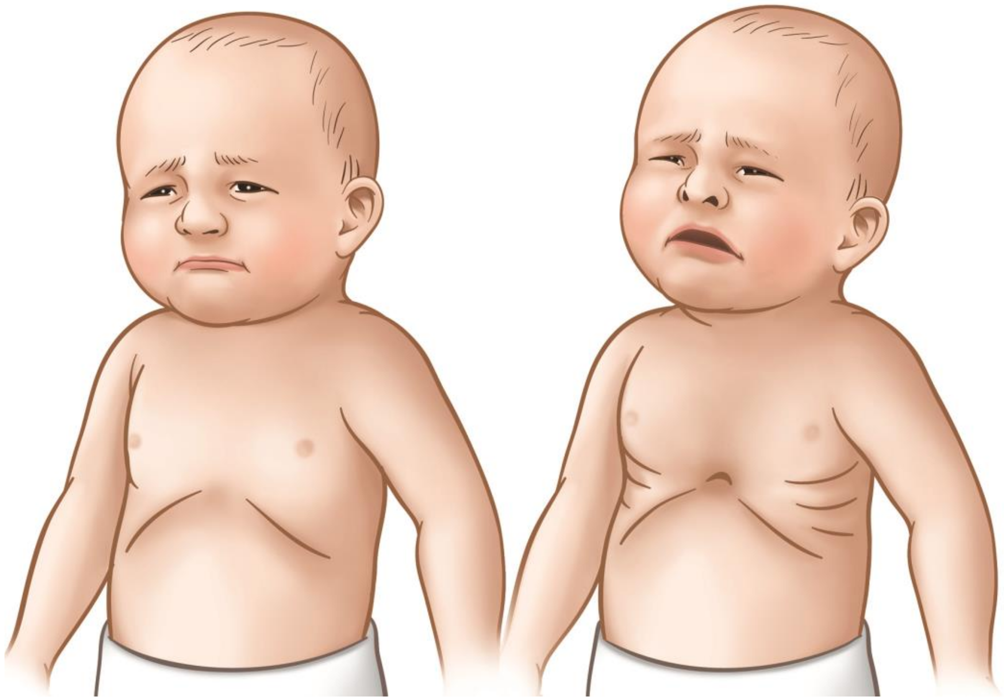


Figure 2: Flow diagram showing approach to hypoxemic respiratory failure

Clinical signs of respiratory distress

1. Respiratory compensation
   - Tachypnea
     - Very rapid rates can be seen!
   - Noisy breathing
   - Work of breathing
     - Accessory muscle use
     - Nasal flaring (increased nasal air flow)
     - Recession/intercostal retractions
     - Grunting (auto-PEEP)
     - Active exhalation with abdo muscles
     - “See-saw” breathing
     - Head bobbing

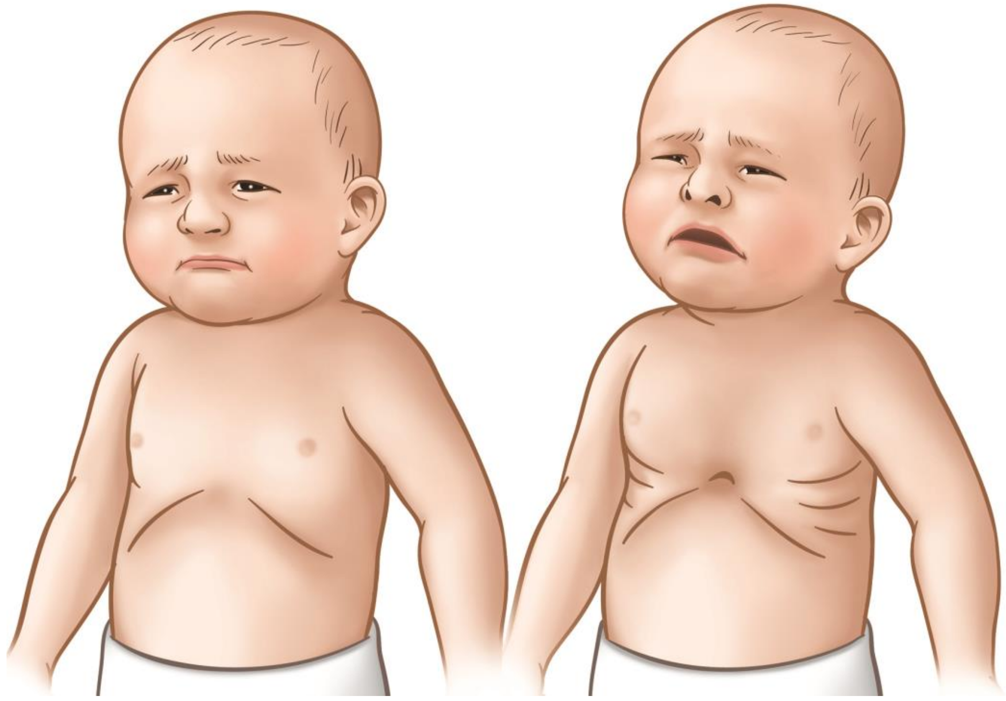


Clinical signs of respiratory distress

2. Sympathetic stimulation
   - Increased HR
   - Increased BP (early)
   - Sweating

3. Tissue hypoxia
   - Altered mental state
   - Decreased HR and Decr BP (late)

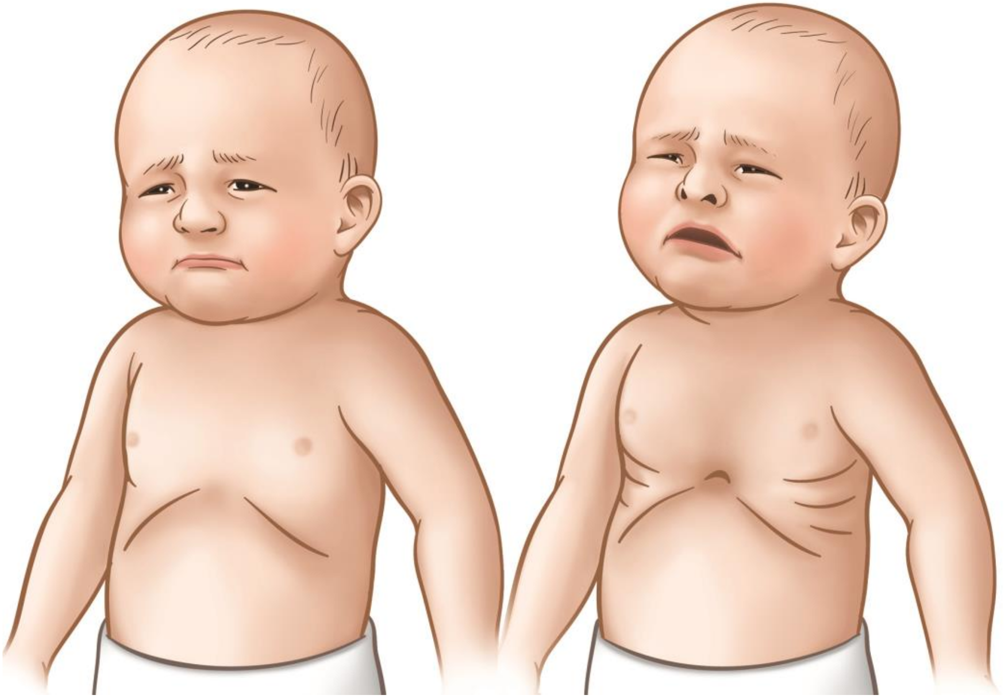
4. Hemoglobin desaturation
   - Cyanosis



Clinical signs of respiratory distress When do we call it failure ?

Frequent clinical reassessments are **key** to recognizing progressive deterioration

Maintaining longitudinal recording of **vital signs** , **oxygen saturations** , changes in **ventilatory support**, **blood gases** and **Xrays** may be helpful



Warning signs that the need for ventilation support is approaching

- Be concerned if
  - Extreme RR (age dependant, > 50-60), apnea/variable pattern
  - Cyanosis or SpO_2 < 90%, despite O_2 support
  - Rising $PaCO_2$
  - CVS deterioration, bradycardia
  - Agitated, confused or comatose
  - Deteriorating despite therapy

Summary of pre-Course reading

- Children's anatomy & physiology different from adult's
- Basic respiratory physiology
  - Oxygen uptake
  - CO_2 removal
- Pathophysiology (Shunt, V/Q mismatch, Dead space)
- Frequent assessments, signs of severity and deterioration warning signs
- Treat the cause

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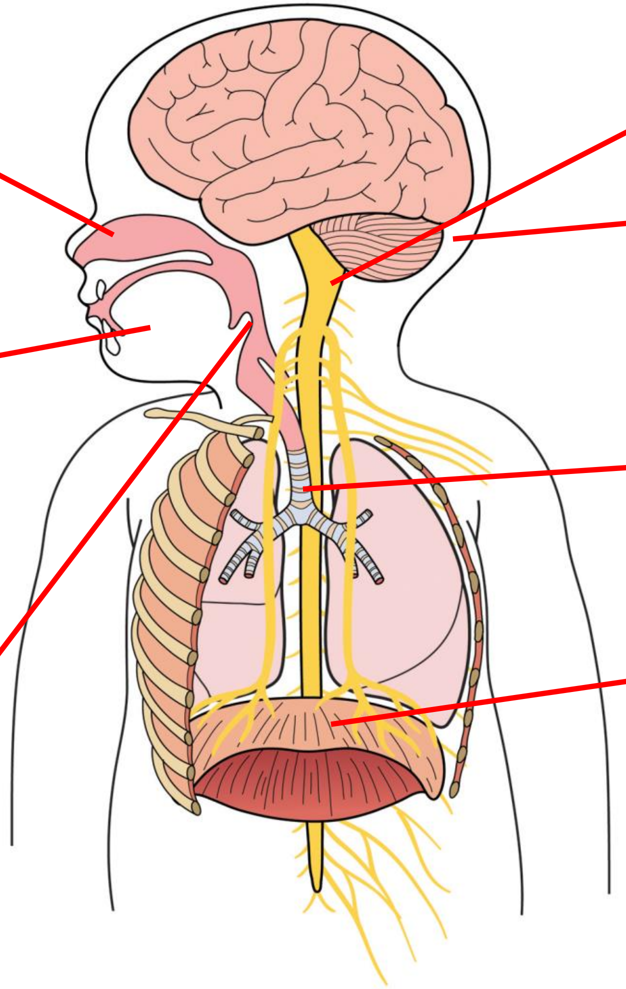

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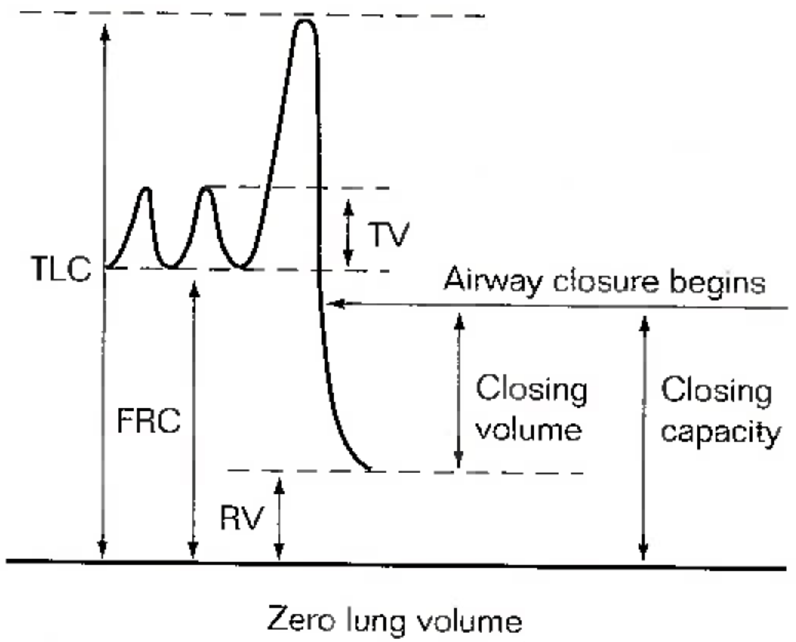

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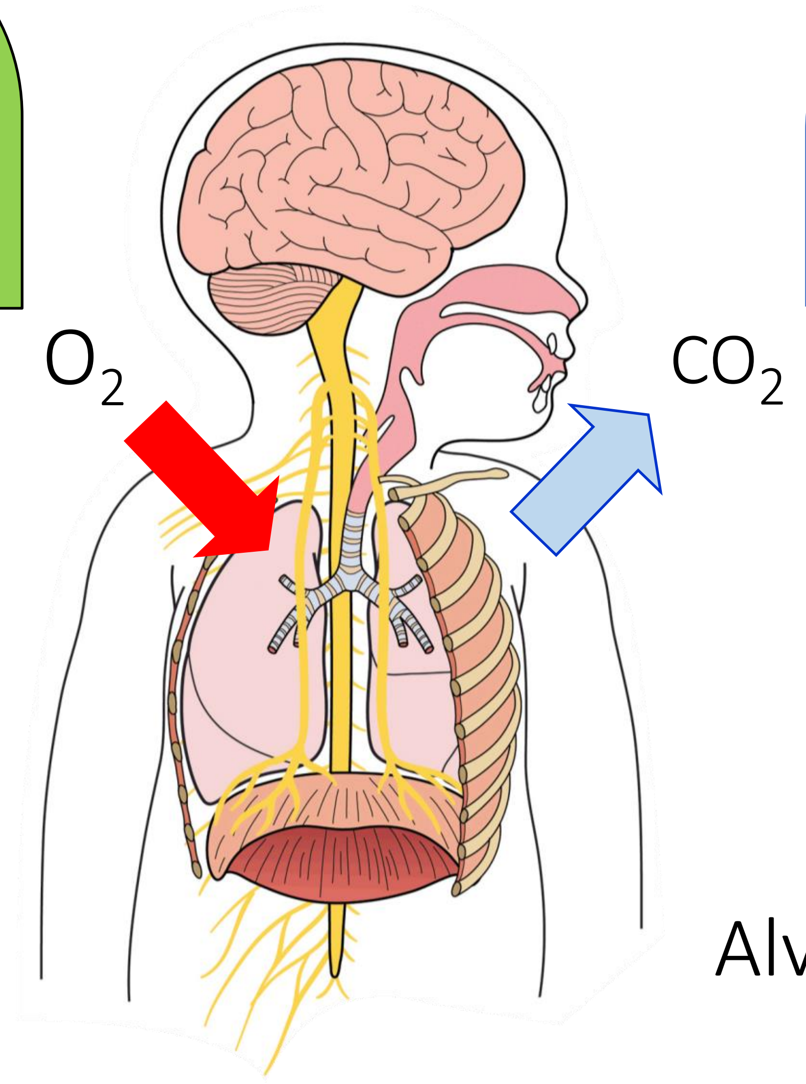
StEP — Stabilization Essentials in Pediatrics

FiO_2
Alv MV
V/Q
D_LO_2

Alv MV
(RR)
(Exh TV)

Normal ventilation



$$\text{Alv MV} = RR \times (V_T - V_{DS})$$

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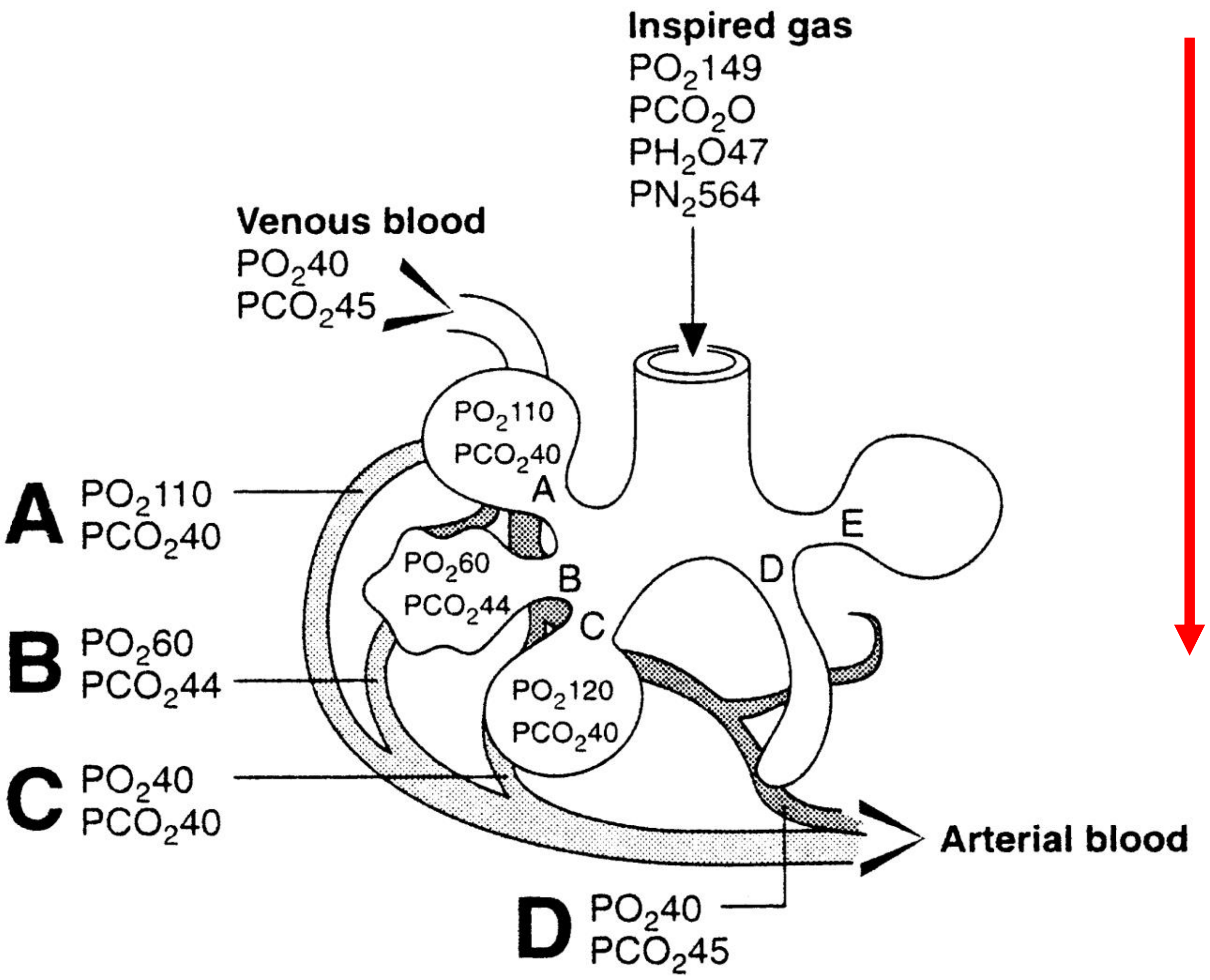

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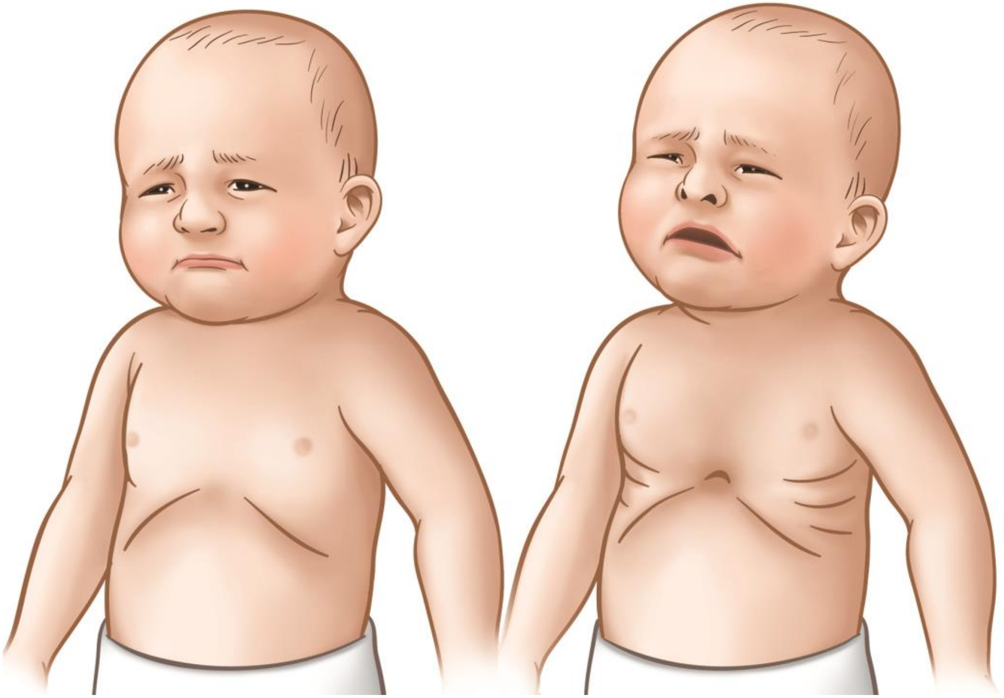

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  - CVS deterioration, bradycardia
  - Agitated, confused or comatose
  - Deteriorating despite therapy

Objectives for today :

- Differentiate the presentation of common respiratory pathologies in critically ill pediatric patients :

  - ❖ Upper airway obstruction
  - ❖ Bronchiolitis
  - ❖ Asthma
  - ❖ Pneumonia

- Develop physiologically based specific management strategies for those conditions, using **case based** demonstrations

Normal HR/RR by age

BC PEWS Vital Signs Reference Card

Age	Heart Rate Beats per minute	Respiratory Rate Breaths per minute	Systolic / Diastolic BP	MAP mmHg
0 – 28 days*	104 – 162	31 – 60	60 – 80 / 30 – 53	40 or higher
1 – 3 months*	104 – 162	31 – 60	73 – 105 / 36 – 68	48 or higher
4 – 11 months*	109 – 159	29 – 53	82 – 105 / 46 – 68	58 – 80
1 – 3 years†	89 – 139	25 – 39	85 – 109 / 37 – 67	53 – 81
4 – 6 years†	71 – 128	17 – 31	91 – 114 / 50 – 74	63 – 87
7 – 11 years†	60 – 114	15 – 28	96 – 121 / 57 – 80	70 – 94
12 plus years†	50 – 104	12 – 25	105 – 136 / 62 – 87	76 – 103
Temperature °C	**Oral:** 35.5 – 37.5, **Axilla:** 36.5 – 37.5, **Rectal:** 36.6 – 38.0, **Temporal:** 36.3 – 37.8			

HR and RR ranges: CTAS 2013
Temperature ranges: CPS 2015
BP ranges: *Modified from American Heart Association (2012). *Pediatric emergency assessment, recognition, and stabilization (PEARS) provider manual.*† National Heart, Lung and Blood Pressure Institute (2004). The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics, 114(2)*, 555-556.

Other useful pediatric pearls

Provincial PEWS Reference Card

Body Weight (kg)	Fluid Requirements Per Day
Below 10 kg	100 mL per kg
10 – 20 kg	1000 mL + 50 mL per kg over 10 kg
Greater than 20 kg	1500 mL + 20 mL per kg over 20 kg
Body Weight (kg)	**Fluid Requirements Per Hour**
Below 10 kg	4 mL per kg
10 – 20 kg	2 mL per kg for each kg greater than 10 kg
Greater than 20 kg	1 mL per kg for each kg greater than 20 kg
Urine Output	**0.5 – 1.0 mL per kg per hr**

Pickard, G. & Abernathy, A.P. (2013). *Dosage calculations, Ninth edition.* Delmar, Cengage Learning.

Case #1

- 2 year old boy presented to ED with moderate to severe work of breathing, saturation in low 80s. Inspiration prolonged and associated with loud stridor. Regular loud barking cough.
  - Started on O2 via non-rebreather mask at 10L/min.
  - Given epinephrine neb with immediate improvement in WOB and resolution of stridor
  - Given oral dexamethasone.
  - After 4 doses of epinephrine at 15-30 min intervals, transient improvement after each. Moderate to severe work of breathing when upset. Stridor at rest goes away post epinephrine neb for 15-30 min. Does not look toxic.
  - VS: Sat 97-97%, RR 45, HR 150, BP 80/35 T38.1
  - Normal CXR and lateral neck x-ray

Worried?

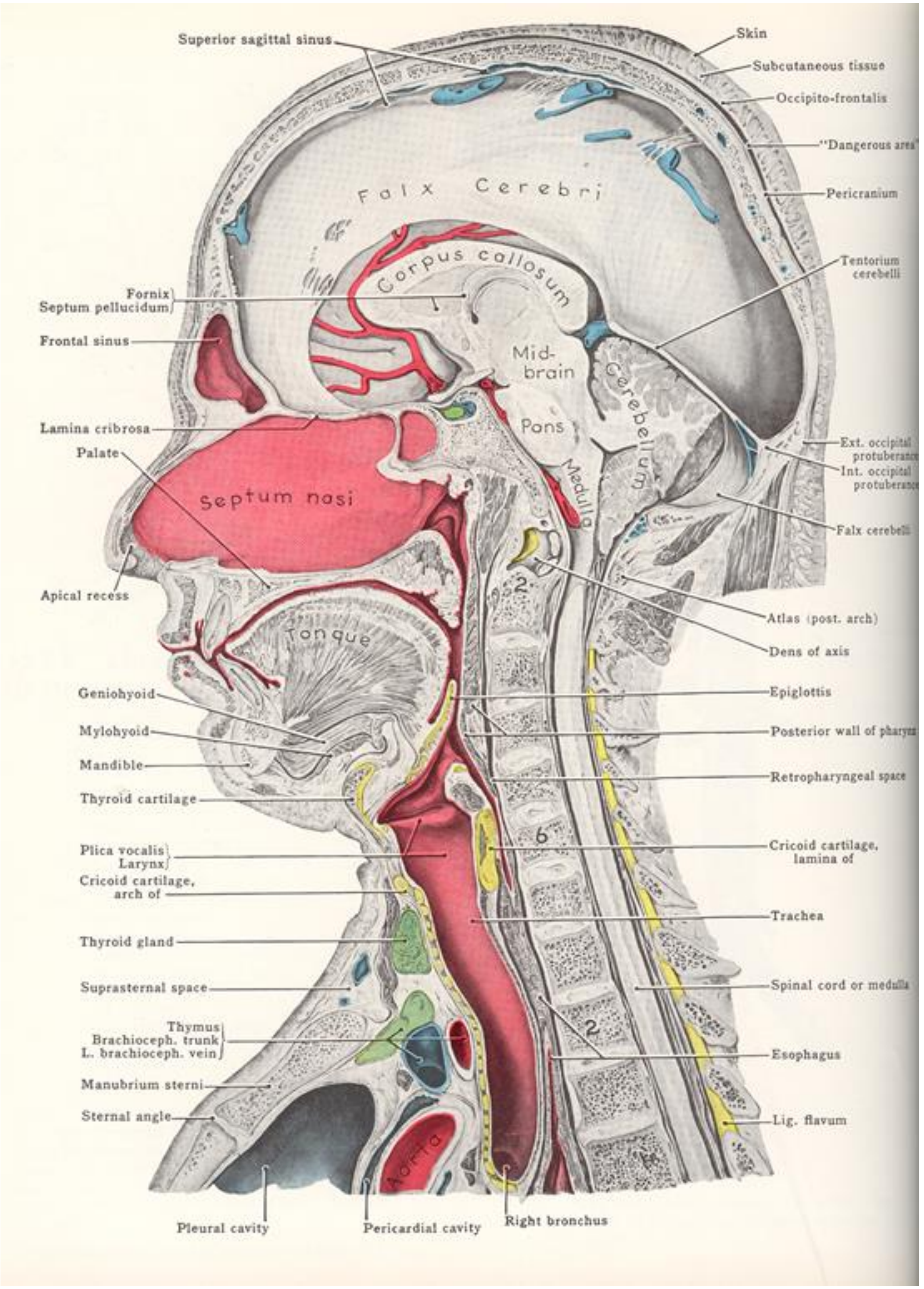
Dx?

Immediate management?

Upper airway obstruction

- Location: supraglottic, glottic, subglottic
- Can be fixed or variable which will affect type of flow limitation
- May be associated age-related airway dynamics
    - Smaller airways, therefore obstruct more easily with intimal edema
    - Less cartilaginous support and therefore more prone to collapse under pressure differential
- Unless the cause of the obstruction is also causing lung disease, then any hypoxia present is most likely due to hypercarbic hypoxia, and should be corrected by an F_iO_2 30%

(Physiology described in pre-reading for Course)



Differential diagnosis

Grouped by level of obstruction

- Supraglottic
  - **Epiglottitis**
  - **Tonsillitis**
  - **Retropharyngeal abscess**
- Glottic
  - **External trauma, burns**
  - **Postinstrumentation**
- Subglottic
  - **Croup**
  - **Bacterial tracheitis**
  - **Mediastinal tumours**
- Multilevel
  - **Foreign body**
  - **Anaphylaxis**
  - **Decreased LOC**

Table 5–3. **Clinical Features of Acute Upper Airway Disorders**

	Supraglottic Disorders	Subglottic Disorders
Stridor	Quiet and wet	Loud
Voice alteration	Muffled	Hoarse
Dysphagia	+	−
Postural preference*	+	−
Barky cough	−	+ especially with croup
Fever	+	+ usually in croup
Toxicity	+	−
Trismus	+ usually in peritonsillar abscess	−
Facial edema	−	+ usually with angioedema

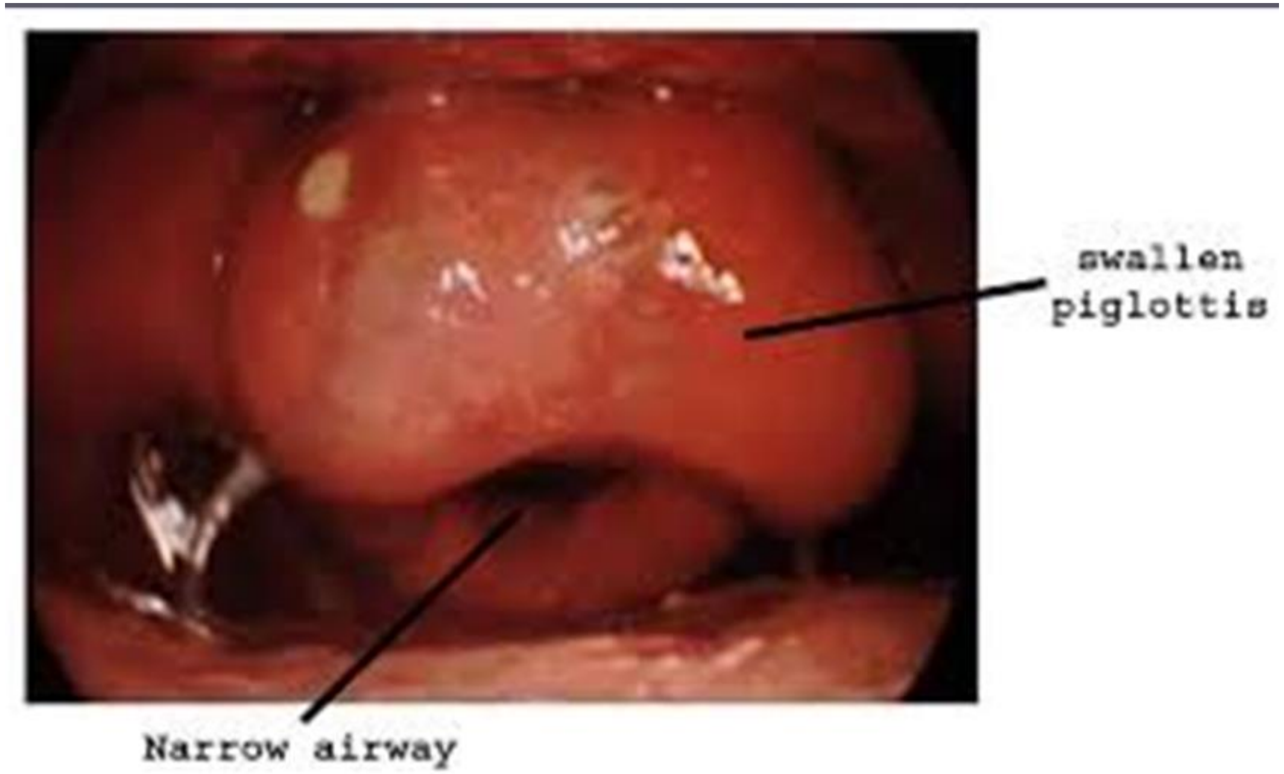
*Epiglottis: patient characteristically sits bolt upright, with neck extended and head held forward; retropharyngeal abscess: child often adopts opisthotonic posture; peritonsillar abscess: child may tilt head toward affected side.

From Davis HW, Gartner JC, Balvis AG, et al. Acute upper airway obstruction: croup and epiglottitis. Pediatr Clin North Am 1981; 28:859.

A few pearls…..

Acute epiglottitis

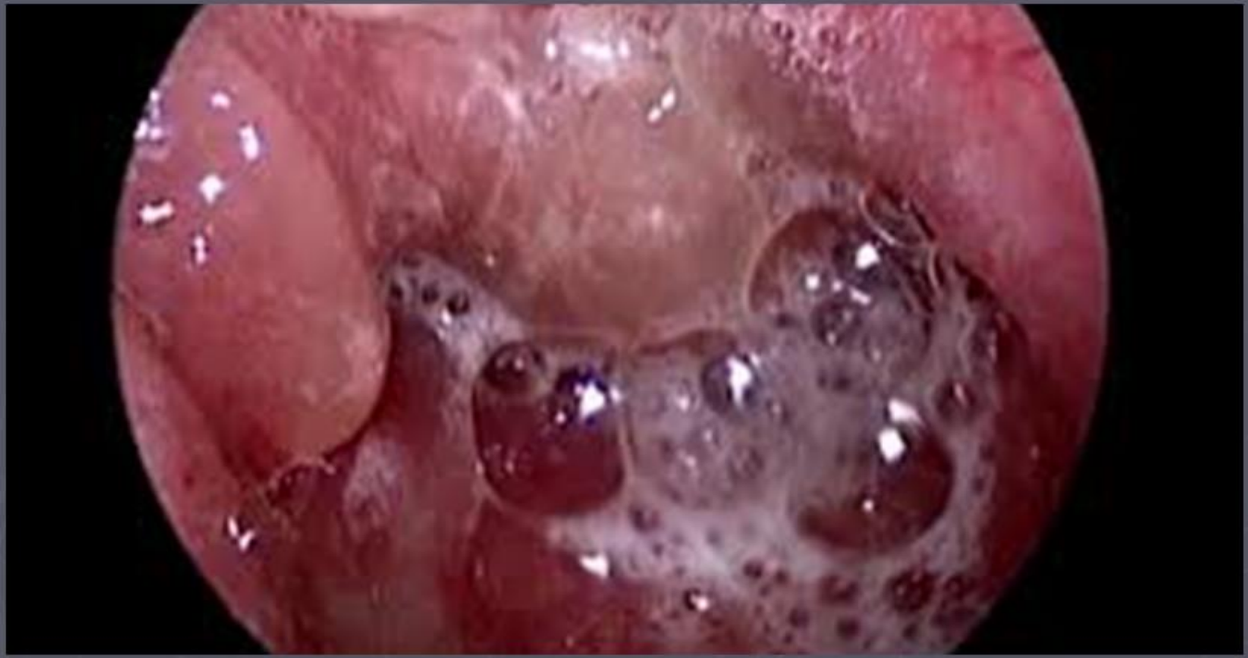
- Disease now virtually eradicated in the pediatric population who have been immunised to BC standard
  - Used to be most commonly caused by Hemophilus influenzae Type B (HIB)



A few pearls.....

Acute epiglottitis

Epiglottitis

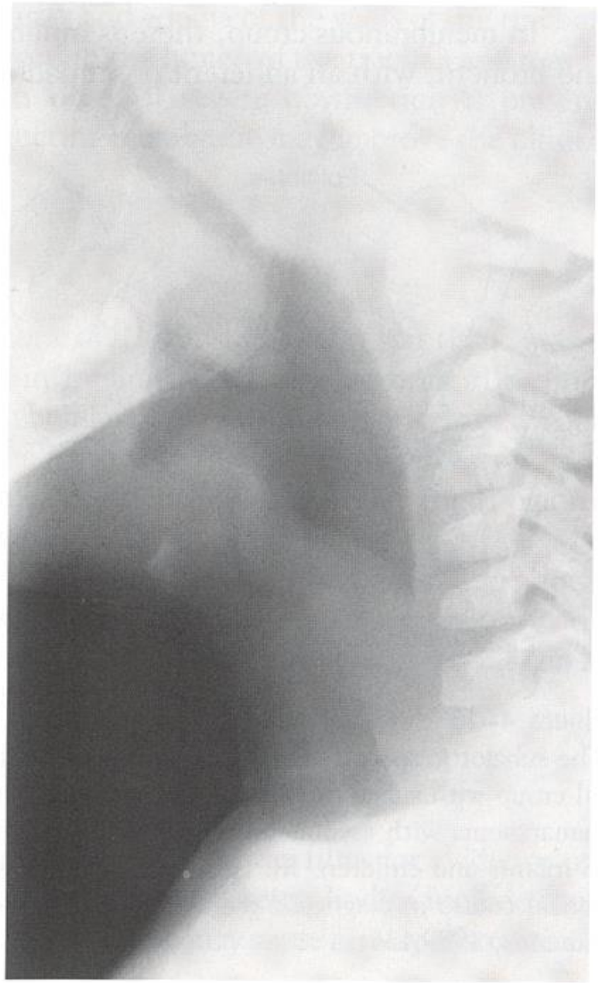


https://www.youtube.com/watch?v=Suesq07cT2Q

A few pearls.....

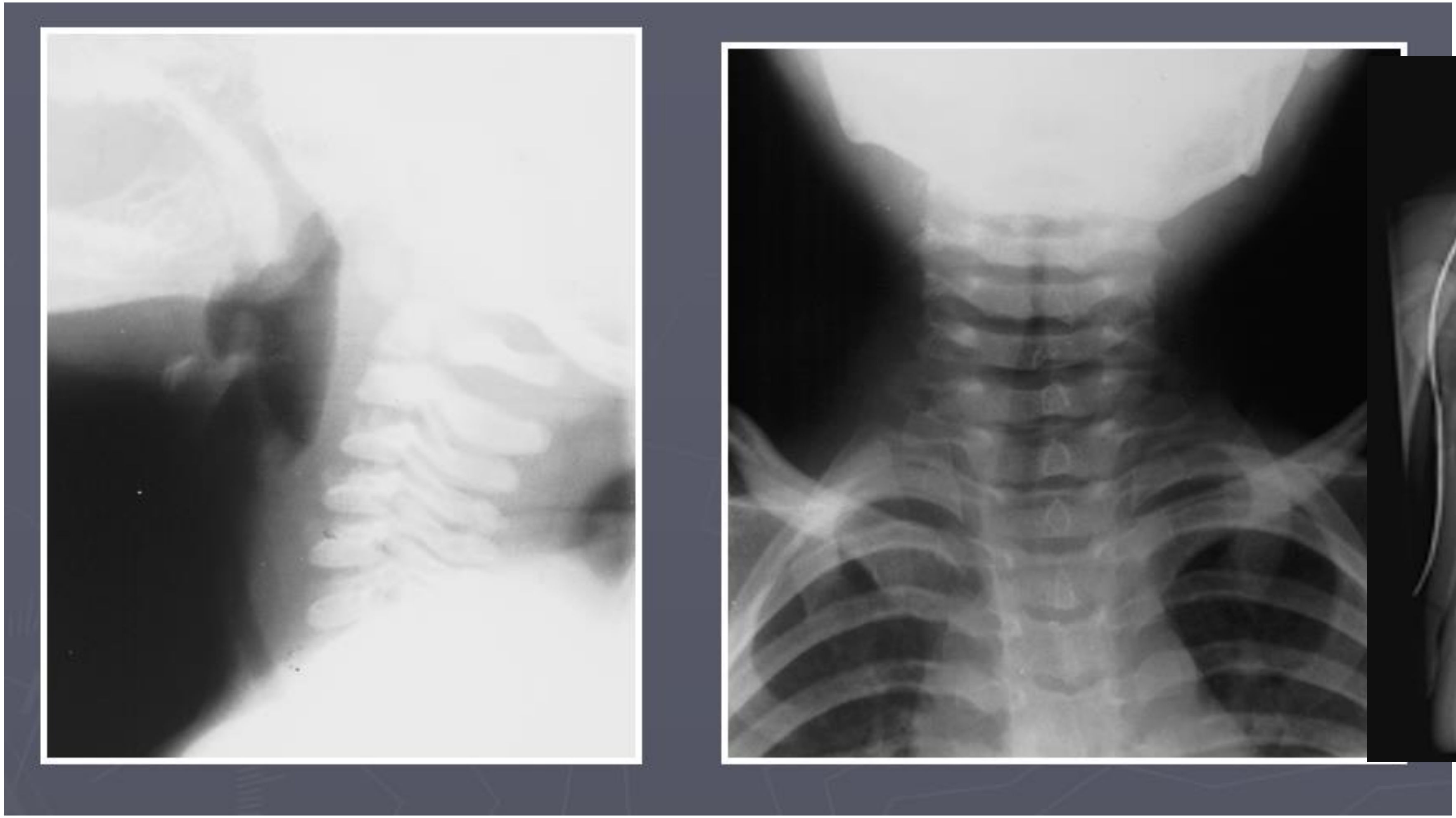
Acute epiglottitis vs croup

Figure 4–14
Acute epiglottis. Upright lateral radiograph shows distension of the hypopharynx, and edema of the epiglottis and aryepiglottic folds. The cervical curvature is reversed as the child's head is held forward.



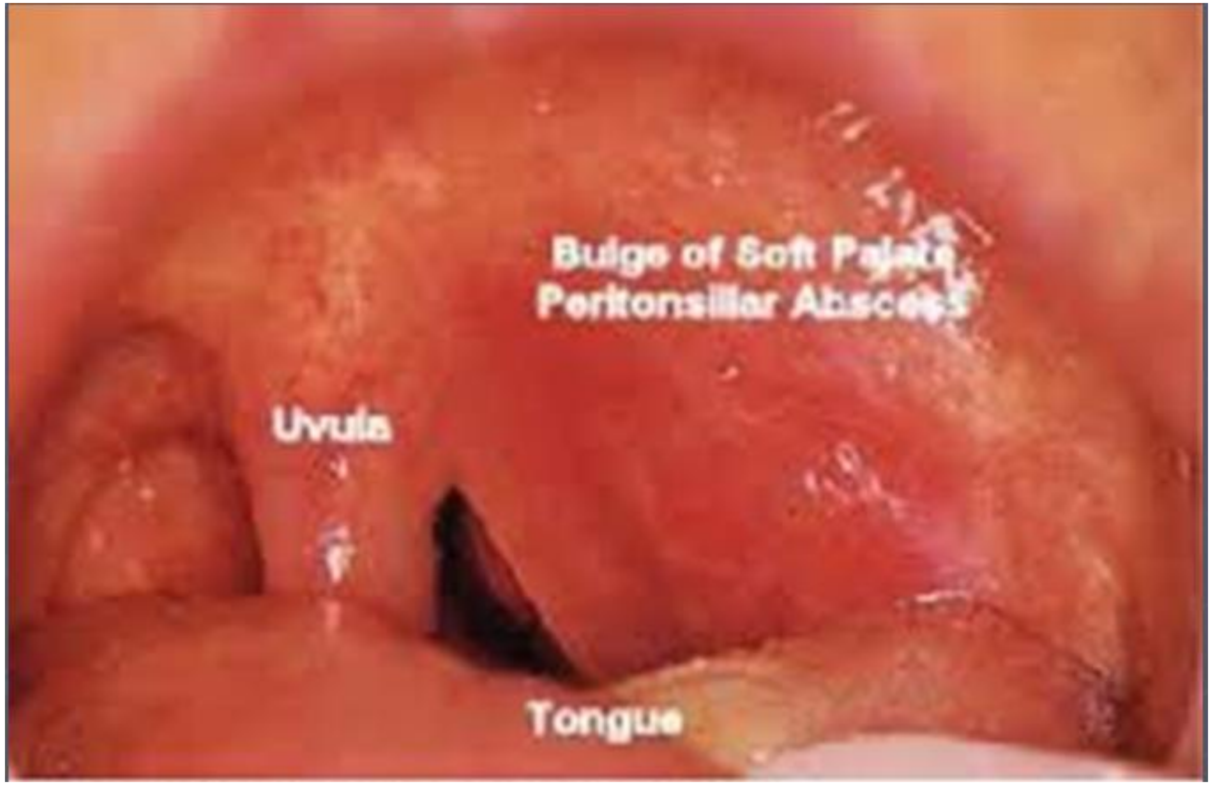
A few pearls…..

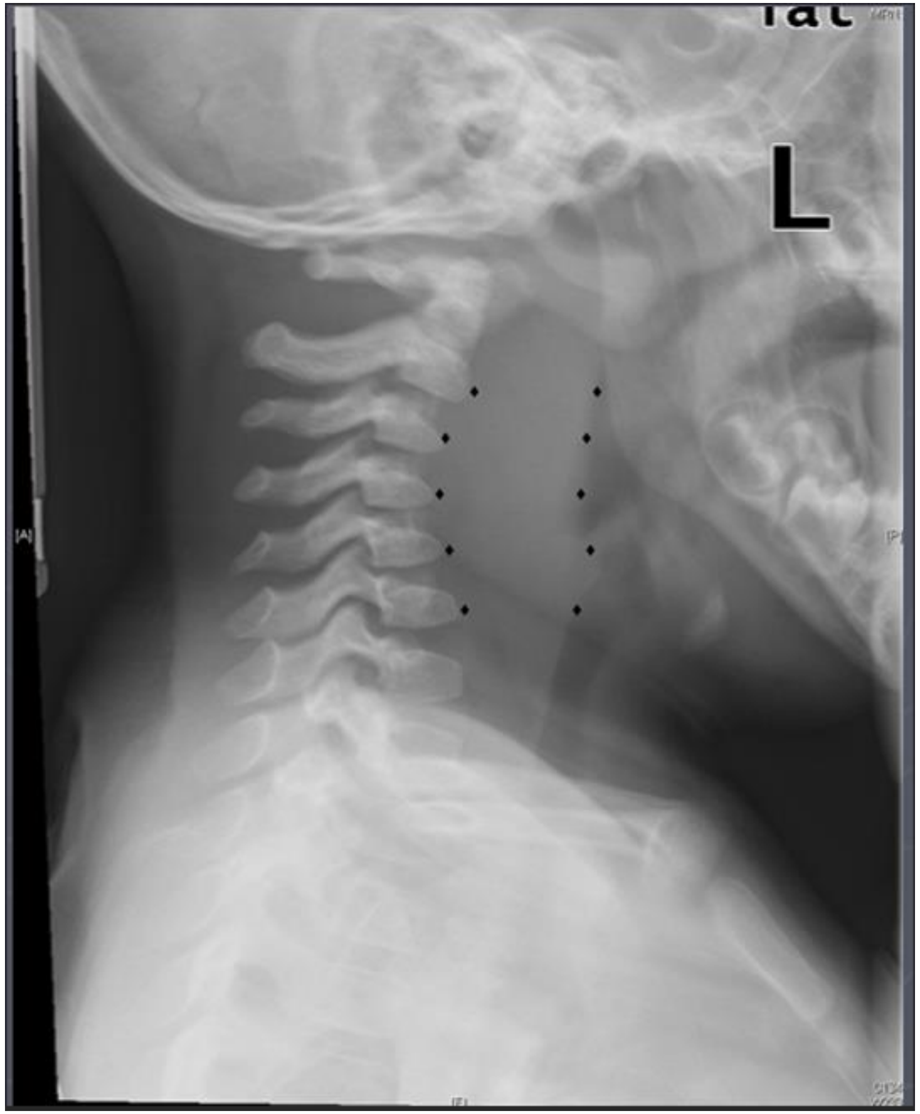
Croup (= acute laryngotracheobronchitis)



A few pearls…..

Retropharyngeal abscess





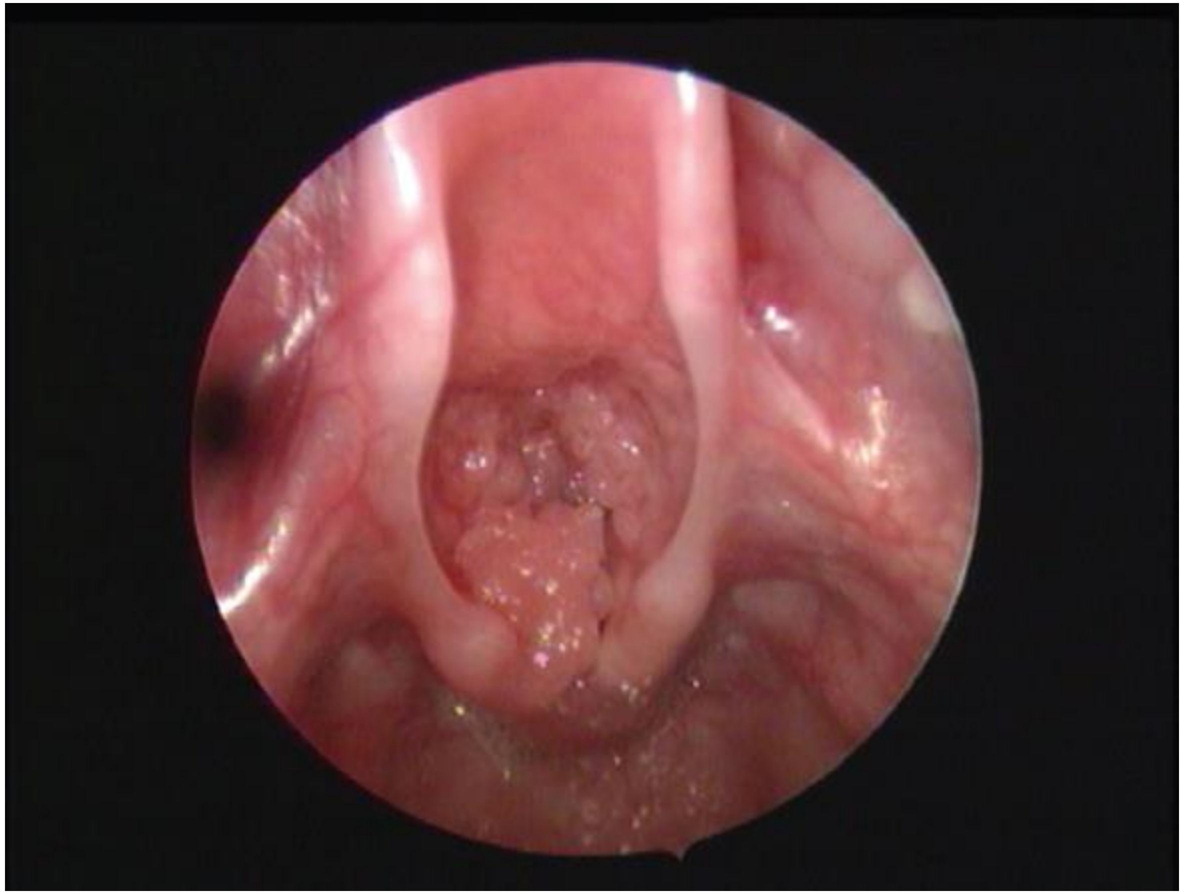
A few pearls…..

Retropharyngeal abscess

Figure 4–12
Retropharyngeal abscess. The airway is displaced anteriorly and to the left (*arrow*) by two hypointense masses that appear to have a hyperintense rim. This retropharyngeal abscess was drained surgically.

A few pearls…..

Bacterial tracheitis



A few pearls…..

Foreign bodies

Pediatrics is fun dad……

A few pearls.....

Foreign bodies

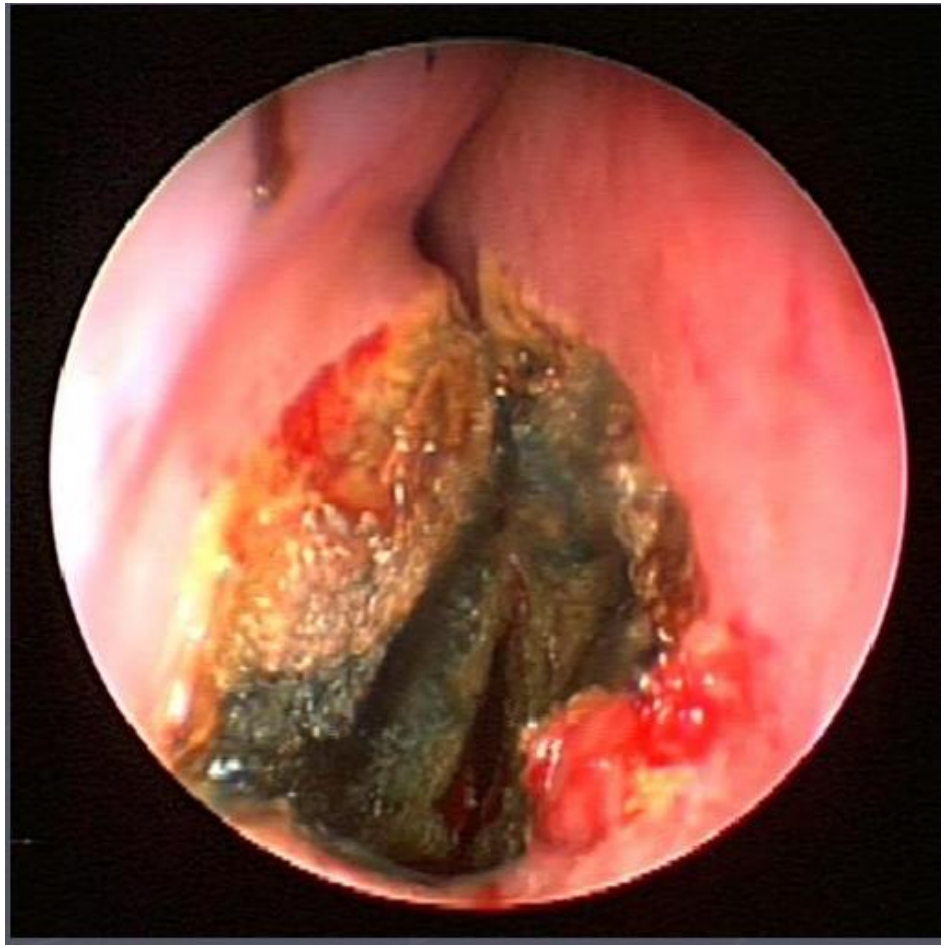
A few pearls.....

Foreign bodies

A few pearls…..

Foreign bodies

Sometimes removing the FB cannot be left until the morning



Returning to our case...........

Hypercarbic hypoxia

- Hypercarbic hypoxemic failure can be completely corrected with 30% FiO2

- Alveolar gas equation
  - PAO2= PiO2– PaCO2/RQ (0.8)
  - PiO2 = FiO2 (Pb-PH20)

Upper airway obstruction without associated lung disease should NOT cause hypoxia.

O2 is correcting hypercarbic hypoxia

Upper airway obstruction - Management

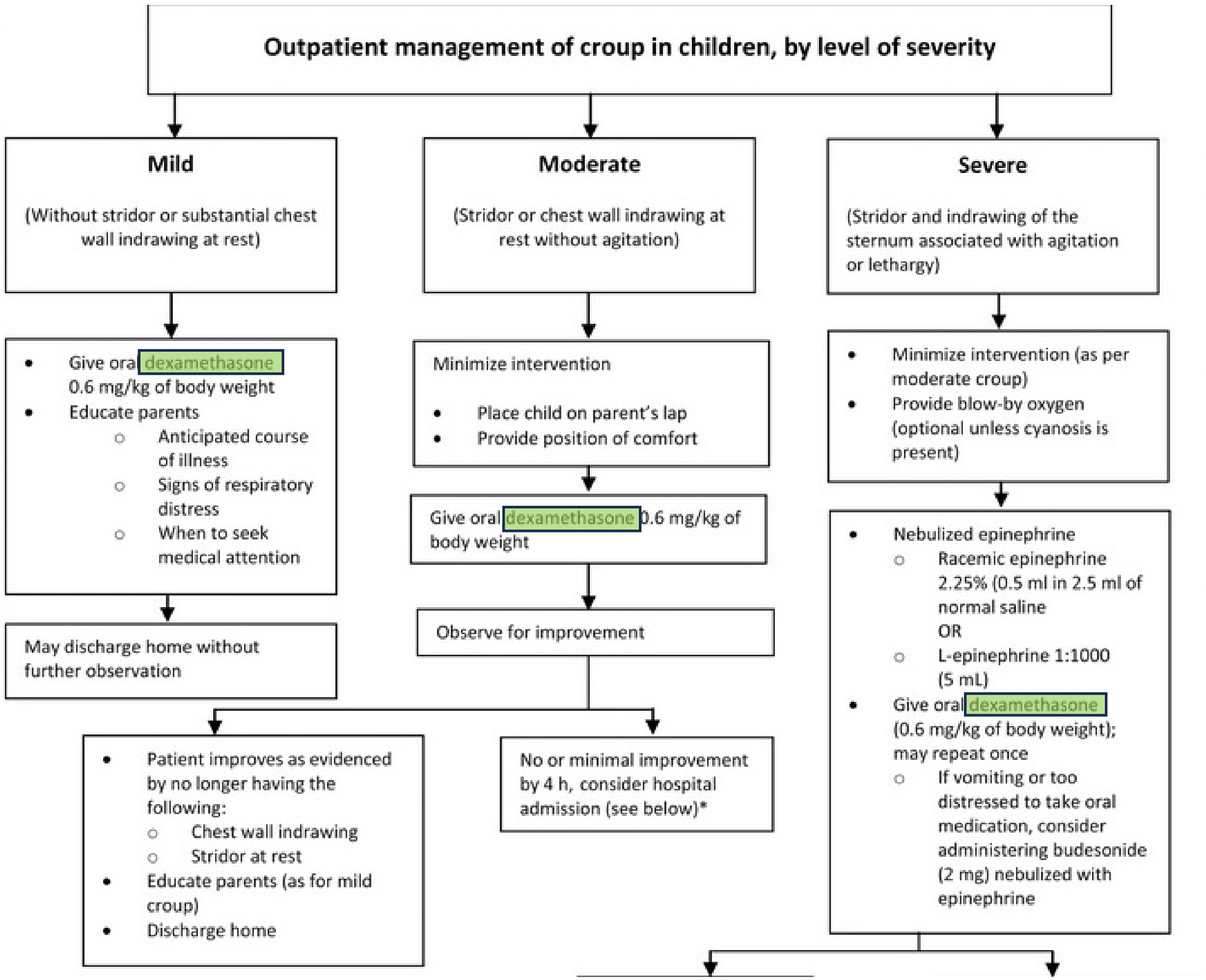
- Oxygen can be given to improve saturations (!)
- Nebulized epinephrine for temporary relief
- Dexamethasone 0.6 mg/kg
- Heliox = temporizing measure
- Emergency airway management = **difficult airway pathway**
  - ETT ½ to 1 size smaller
- Treat specific cause

High risk of deterioration and complete obstruction if upset, sedated, repositioned

Delay investigation until airway is secure

Canadian Pediatric Society Guidelines for management of croup in the ER

Paediatr Child Health 22(3):166-169



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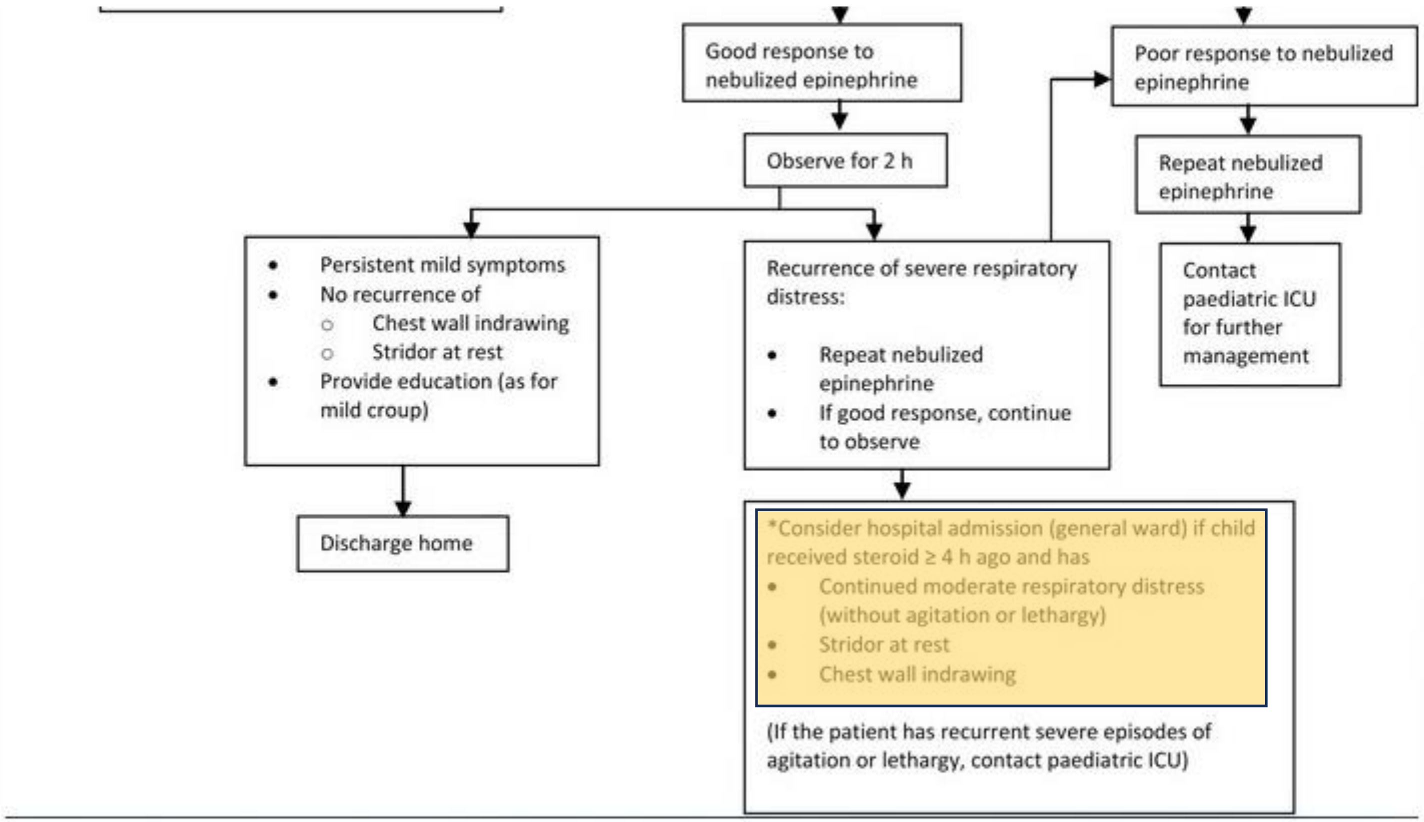


Recommended reading :

trekk bottom line recommendations for Croup

Reference : https://cms.trekk.ca/wp-content/uploads/2023/11/2023-08-21_BLR_Croup_v4.0_FINAL.pdf

This document is due for a review in 2025 and may be become incorporated into the BCCH Critical Care resources

It has no algorithm as such in this version but has a number of useful "criteria" sections that are not covered in the CPS algorithm :

- Criteria for safe discharge home
- Criteria for hospital admission
- Criteria for transfer to PICU

It also has a more detailed approach to the management of patients at the sicker end of the scale : it is well worth a read

Worst case scenario

Intubation: Indications

- Hypoxia
- Hypercarbia
- Airway patency
- Airway protection
- Tests and procedures

Intubation - preparation

- Personnel : who will intubate, back up?
- Equipment
- Medications
  - Induction
  - Resuscitation drugs/fluids
- Checklist
- *Intubating a patient with croup should not be undertaken lightly and ideally should involve prior discussion with the PICU Intensivist, the on-site availability of an experienced pediatric ENT Surgeon and the most experienced "pediatric difficult airway" anesthetist available*

"Hope for the best, but prepare for the worst"

AIRWAY MANAGEMENT

Endotracheal Intubation

BEFORE Intubation

- Assessment
- Equipment
- Checklist
- Preparation
- Medication

In-a-Hurry Summary

DURING Intubation

- Basic Steps
- Pediatric Endotracheal Intubation Video

In-a-Hurry Summary

AFTER Intubation

- Confirmation
- Airway Securement
- Ventilation Goals
- Maintenance

In-a-Hurry Summary

Respiratory Equipment

← Pediatric Critical Care Home

DRUG RESOURCES

- Weight-based Drug Sheets
- Drug Formulary
- BCCH Empiric Antimicrobial Guide
- Firstline App (Antimicrobials)

WEIGHT in kg	12
Average AGE for weight (YEARS)	2

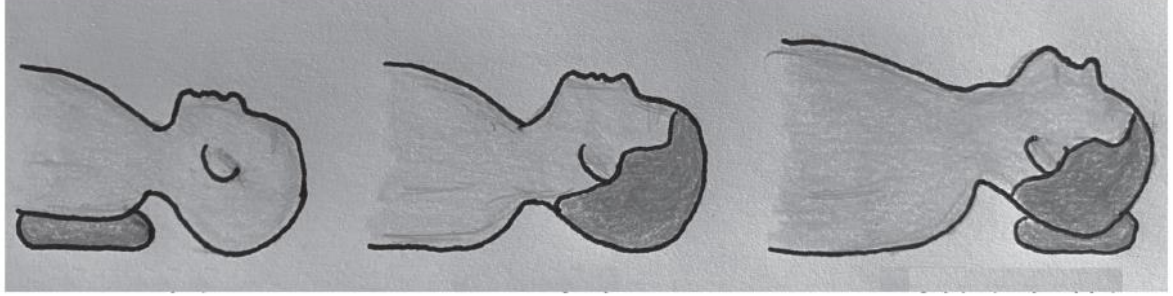
PEDIATRIC MEDICATIONS DOSE CALCULATOR

Children's Hospital

DRUG	dose/kg	dose	concentration	GIVE	route	additional info
Resuscitation						
ADENOSINE	0.1 mg/kg	1.2 mg	3 mg/mL	0.4 mL	IV	Max 6 mg. If less than 0.2 mL dilute with NaCl. Rapid push
CALCIUM CHLORIDE 10%	20 mg/kg	240 mg	100 mg/mL	2.4 mL	IV	Max 1000 mg
CALCIUM GLUCONATE 10%	100 mg/kg	1200 mg	100 mg/mL	12 mL	IV	60-100 mg/kg/dose. Max 3000 mg
DEXTROSE (50% glucose)	0.5 g/kg	6 g	0.5 g/mL	12 mL	IV	Dilute 1:1 with sterile water. Max 50 mL Max 200 mg/kg/min
DEXTROSE (10% glucose)	0.5 g/kg	6 g	0.1 g/mL	60 mL	IV	Max 250 mL. Max 200 mg/kg/min
EPINEPHRINE (Resusc)	10 mcg/kg	120 mcg	0.1 mg/mL	1.2 mL	IV	0.1 mg/mL = 100 mcg/mL; Check strength
EPINEPHRINE (low dose push)	1 mcg/kg	12 mcg	0.01 mg/mL	1.2 mL	IV	0.01 mg/mL = 10 mcg/mL; Not a standard concentration, needs to be mixed
3% SODIUM CHLORIDE	5 mL/kg	60 mL	0.514 mmol/mL	60 mL	IV	Max 300 mL. Give over 10 min
MANNITOL (20%)	1 g/kg	12 g	0.2 g/mL	60 mL	IV	Max 50 g. Filter required. Push over 3-5 min
NALOXONE	0.1 mg/kg	1.2 mg	0.4 mg/mL	3 mL	IV/IM	Max 2 mg/dose. Push over 30 sec. Repeat q 2 min PRN
Intubation Medications						
DRUG	dose/kg	dose	concentration	GIVE	route	additional info
KETAMINE	1 mg/kg	12 mg	10 mg/mL	1.2 mL	IV	Push over 1 min
ROCURONIUM	1 mg/kg	12 mg	10 mg/mL	1.2 mL	IV	Push over 5 sec
FENTANYL	1 mcg/kg	12 mcg	50 mcg/mL	0.24 mL	IV	1-2 mcg/kg/dose range. Max 50 mcg. Push over 3-5 min
Analgesia & Sedation						
DRUG	dose/kg	dose	concentration	GIVE	route	additional info
KETAMINE	1 mg/kg	12 mg	10 mg/mL	1.2 mL	IV	Can repeat dose. Push over 1 min
MORPHINE	0.05 mg/kg	0.6 mg	10 mg/mL	0.06 mL	IV	Max 5 mg. Push over 5 min
MIDAZOLAM	0.05 mg/kg	0.6 mg	5 mg/mL	0.12 mL	IV	Max 8 mg. Push over 2 min
Anaphylaxis						
DRUG	dose/kg	dose	concentration	GIVE	route	additional info
EPINEPHRINE	0.01 mg/kg	0.12 mg	1 mg/mL	0.12 mL	IM	Max 0.5 mg/dose 0.01 mg/kg = 10 mcg/kg
Seizures						
DRUG	dose/kg	dose	concentration	GIVE	route	additional info
LevETIRAcetam	60 mg/kg	720 mg	100 mg/mL	7.2 mL	IV	Max 4500 mg. Refer to parenteral manual for administration instructions
PHENYTOIN	20 mg/kg	240 mg	50 mg/mL	4.8 mL	IV	Max 1500 mg. Refer to parenteral manual for administration instructions
PHENOBARBITAL	20 mg/kg	240 mg	120 mg/mL	2 mL	IV	Max 1000 mg. Refer to parenteral manual for administration instructions
LORAZEPAM	0.1 mg/kg	1.2 mg	4 mg/mL	0.3 mL	IV	Max 4 mg. Refer to parenteral manual for administration instructions

Last update Sept 24, 2024

SOAP ME STABLE



- **S**uction: preferably Yankauer suction, with the suction turned on and working
- **O**xygen: flowing at an appropriate rate for pre-oxygenation
- **A**ssistant:
- **P**osition: sniffing position to optimize laryngeal view
- **M**onitoring: SaO2, ETCO2 (continuous), ECG, NIBP, stethoscope, crash cart
- **E**nvironment: room to move, equipment within reach
- **S**trapping/taping: to secure ETT, cut and ready
- **T**herapeutics: induction and emergency drugs, fluids
- **A**djuncts (airway): OPA, NPA, bougie, LMA
- **B**ag and mask: right size, pressure tested +/- manometer
- **L**aryngoscope: 2 tested and working laryngoscopy +/- videolaryngoscope
- **E**ndotracheal tube: appropriate size and one size below, preferably cuffed, stylet ALWAYS

Predictors of difficult airways

- Dysmorphic facial features / syndromes
- Mallampati grade 3-4
- Stridor/UAO
- Physical features:
  - Limited mouth opening
  - High arch or narrow palate
  - Small mandible
  - Short/wide neck
  - Limited head and neck range of motion

JAMA 2013

HELP ME

Case #2

- 10 months old baby presented to ED with 4/7 rhinorrhea and cough and 1/7 WOB. On arrival sats 88% on RA. He has been started on LFNC with good response in his sats.
  - VS: RR 70 , Sat 92% on 2L/min LFNC, HR 140s, BP 70/35, T 38.2
  - Gas: 7.30-58-23 lactate 1.5
  - Exam: moderate WOB with supra-sternal and subcostal retractions, wheeze, good air entry, normal LOC/activity. “Happy wheezer”

Worried?
Dx?
Immediate management?

Bronchiolitis

- RSV most common pathogen, but can be caused by a plethora of viruses
- Diagnosis is clinical, made on history and physical examination
- Management is supportive
  - Hydration (enteral>IV), avoid fluid overload
  - Oxygenation/ventilatory support

Severity factors:

- Apnea
- Respiratory acidosis
- Altered LOC/hypotonia
- Persistent hypoxemia
- Impending respiratory failure

- *Age: < 6 weeks*
- *Prematurity*
- *Chronic lung disease*
- *Congenital heart disease*
- *Neuromuscular disorders*
- *Immunodeficiency*

Recommended reading : https://www.childhealthbc.ca/sites/default/files/Bronchiolitis-Less-is-Best-V1-2023%20%281%29.pdf

Case #2 continued

- You have decided to start this child on HFNC 2L/kg/min FiO_2 30% for his WOB and mild respiratory acidosis.
- Saturations and RR/WOB have improved.
- The resident asks you why do infants get so sick with RSV and adults only get a cold?

Resistance

$$\frac{8 \times \text{length} \times \text{viscosity}}{\pi \times (\text{radius})^4}$$

	Normal	Edema (1mm)	Area/resistance
Infants	4mm	2mm	↓75% / ↑ 16x
Adults	8 mm	6 mm	↓44% / ↑ 3x

Case #2 Continued

- Despite an initial improvement, the patient deteriorated overnight and was initiated on BiPAP.
- Despite BiPAP he has continued to deteriorate. On assessment this morning
  - VS: HR 180, BP 70/35 (45), CR 3-4 sec, RR 65, sat 95%
  - Gas 7.31-50-17 lactate 3.2

Bronchiolitis-Management

Provincial Health Services Authority

- Symptomatic management: oxygen, hydration
- No medication recommended routine
  - B2-agonists "trial" no longer be considered
  - Antibiotics can be considered if strong suspicion/evidence of secondary bacterial pneumonia
- Respiratory support: HFNC, NIV, IPPV
  - Respiratory toilet: suctioning
  - Low respiratory rate/optimize expiratory time for obstructive lung disease (if sedated/paralyzed)
  - Permissive hypercapnia

Case # 2 Continued

- The patient continued to deteriorate despite optimising BiPAP
- Central apnea became a significant problem requiring frequent intervention.
- He was intubated without complication and stabilised on PRVC ventilation

Extrapulmonary manifestations that may accompany bronchiolitis

Extra-pulmonary manifestations

- CNS: central apnea (seizures, encephalopathy)
- *CVS: myocarditis, arrhythmias, pericarditis, pHTN*
- *Liver: transaminitis*
- *Endocrine: SIADH*

Case #3

- 4 year old boy with history of asthma. 2/7 rhinorrhea/cough. 1/7 WOB on Ventolin q4h at home. On admission sats in low 80s, severe WOB. Started on the asthma protocol.
  - Has received btb Ventolin/Atrovent x3, dexamethasone po, $MgSo_4$ IV, methylpred IV and is now on Ventolin q 30 min via nebulizer
  - On HFNC 2L/kg at 50% FiO_2. Sats 92-94%. RR 30. HR 130-140 bpm. BP 85/42
  - The child is asleep in his mother's arm during your examination. You cannot appreciate any wheeze, but note diminished air entry throughout. There is moderate-severe WOB.
    - 7.2-60-22 lactate 5.2
    - CXR: no pneumothorax, hyperinflated +++

Worried?
Dx?
Immediate management?

https://www.childhealthbc.ca/pcc/hurry

ACUTE CONDITIONS

Acute Agitation

Anaphylaxis

Asthma

Asthma

- Recognition
- Management – Mild to Moderate (PRAM Score 0-7)
- Management – Severe (PRAM SCORE 8-12)
- Medication

In-a-Hurry Summary

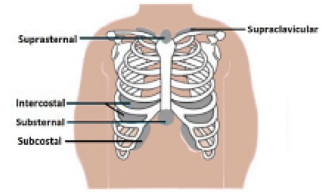
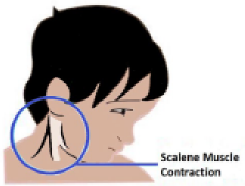
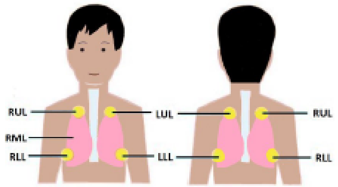
Non Invasive Positive Pressure Ventilation (NIPPV)

- Equipment
- Set Up & Management
- Settings on BiPAP
- Medication Administration

In-a-Hurry Summary

Asthma –In a hurry – Recognition – PRAM Scoring

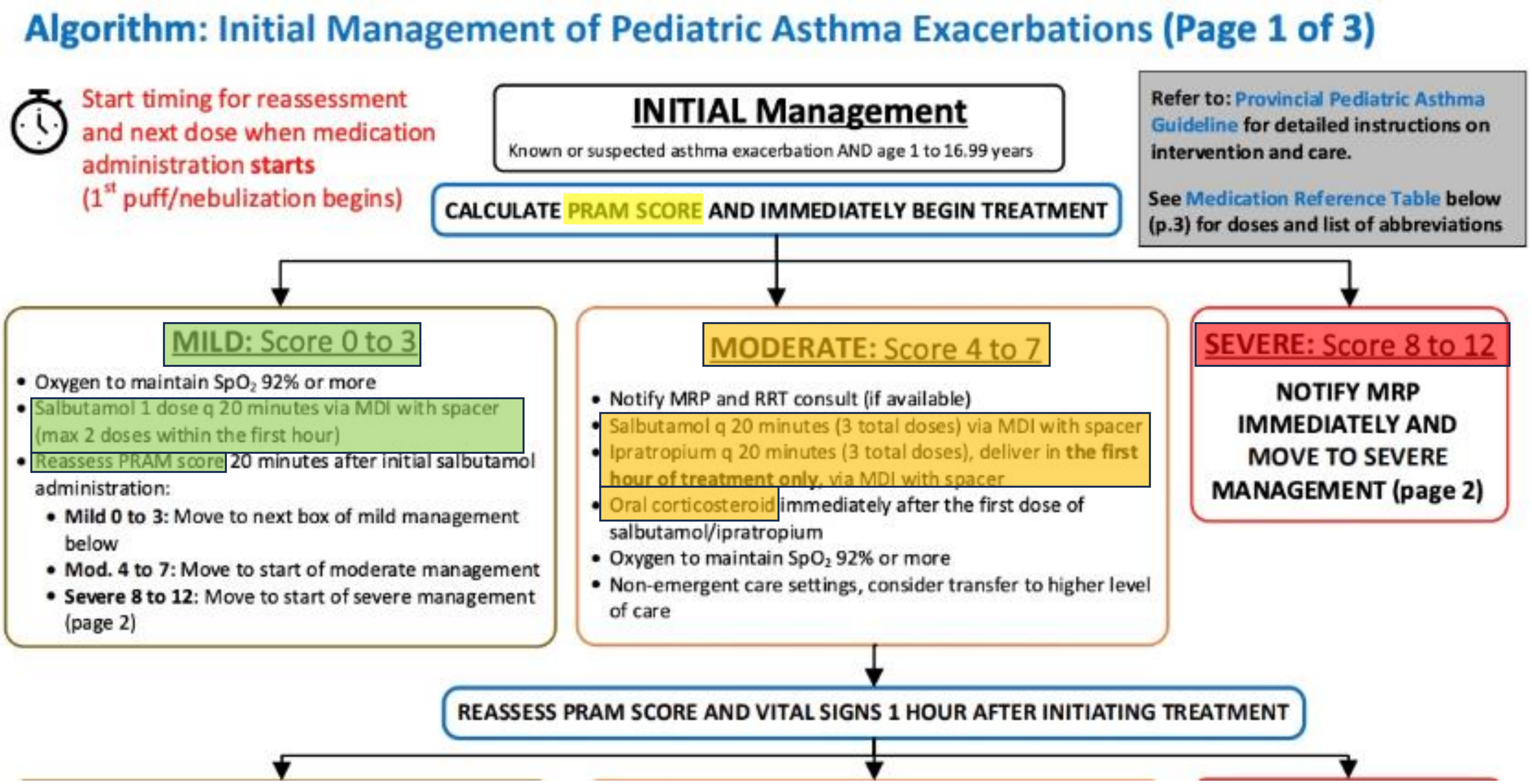
PRAM Scoring Table*

Criterions	Description	Score	Notes
Oxygen Saturation	Greater than or equal to 95%	0	O_2 saturation must be measured with the patient breathing ambient air until stabilization of the oximetry value for at least 1 minute.
	92-94%	1	**Turn off supplementary oxygen** when measuring PRAM. If SpO_2 falls to less than 92% you can turn oxygen back on immediately as they have automatically scored maximum (2) points.
	Less than 92%	2	
Suprasternal Retraction 	Absent	0	Suprasternal retraction is visible indrawing of the skin above the sternum and between the sterno-cleido-mastoid muscle with every intake of breath. It may cause an involuntary shoulder shrug in small children. **This is a visual assessment.**
	Present	2	
Scalene Muscle Contraction 	Absent	0	The scalenes are deep cervical muscles located in the floor of the lateral aspect of the neck. Scalene contraction cannot be seen. **This is a palpable assessment.** It occurs only in those with severe asthma exacerbations. Scalene muscles are bordered on each side by the sterno-cleido-mastoid muscle, the trapezius (in the back) and the clavicle.
	Present	2	
Air Entry 	Normal	0	**In cases of asymmetry, the most severely affected lung field determines the rating.** Use lung fields to grade air entry.
	Decreased at bases	1	**Lung field=two contiguous VERTICAL auscultation zones of the major lobes:** Posterior lung fields: RUL & RLL or LUL & LLL Right anterior lung field: RUL & RML Left anterior lung field: LUL & LLL
	Decreased at the apex and the base	2	
	Minimal or absent	3	
Wheezing	Absent	0	Use auscultation zones to grade wheeze. **At least two auscultation zones must be affected to influence the rating.**
	Expiratory only	1	In case of asymmetry, the two most severely affected auscultation zones, irrespective of their location (RUL, RML, RLL, LUL, LLL), will determine the rating criteria.
	Inspiratory (± expiratory)	2	
	Audible without stethoscope or silent chest (minimal or no air entry)	3	
PRAM Score Total	**0 – 3 Mild**	**4 – 7 Moderate**	**8 – 12 Severe**

LLL: Left lower lobe LUL: Left upper lobe O_2: Oxygen RLL: Right lower lobe RML: Right middle lobe RUL: Right upper lobe SpO_2: Oxygen saturations

Adapted from: Ducharme, F. M., Chalut, D., Plotnick, L., Savdie, C., Kudirka, D., Zhang, X., Meng, L., & McGillivray, (2008). The Pediatric Respiratory Assessment Measure: A valid clinical score for assessing acute asthma severity from toddlers to teenagers. Journal of Pediatrics, 152(4), 476-80.

Asthma – In a hurry – Management PRAM 0-7



Start timing for reassessment and next dose when medication administration **starts** (1st puff/nebulization begins)

Refer to: Provincial Pediatric Asthma Guideline for detailed instructions on intervention and care.

See Medication Reference Table below (p.3) for doses and list of abbreviations

Signs of Impending Respiratory Failure

- Decreased level of consciousness
- Agitation
- Cyanosis
- Decreased respiratory effort
- Confusion

SEVERE: Score 8 to 12

- Inhaled salbutamol and ipratropium MDI with spacer or nebulizer q 20 minutes (3 total doses)
  - If salbutamol q 20 minutes x 3 already provided, administer continuous nebulized salbutamol
  - If ipratropium already provided during management, do not administer again
- Establish vascular access
- If not already provided, administer:
  - MethylPREDNISolone IV, even if PO steroid already provided
- Continuous SpO_2, heart rate and respiratory rate monitoring
- Most responsible physician at bedside, consult RRT (if available)
- Consider early respiratory support and magnesium sulfate infusion (see below for further recommendations)
- Consult local pediatrician on-call; if no pediatrician call CHARLiE via ZOOM/phone and a higher level of care center via PTN
- Rural/remote sites consider/prepare transfer to higher level of care

REASSESS PRAM SCORE 1 HOUR AFTER INITIATING TREATMENT

MILD: Score 0 to 3 or MODERATE: Score 4 to 7

Reassess vital signs and PRAM q 30 min x 2 (salbutamol 1 dose q 30 to 60 minutes); then

Move to **MILD** or **MODERATE** management (page 1)

SEVERE: Score 8 to 12

- Begin of maintain continuous administration of nebulized salbutamol
- If not already provided, adminster:
  - MethylPREDNISolone IV (even if PO steroid already provided)
  - Magnesium sulfate IV (following appropriate health authority/agency guidelines). Monitor BP q 5 minutes during infusion, then q 30 minutes
- If signs of circulatory compromise, provide isotonic 10 to 20mL/kg bolus (max 1L) over 10-20 minutes to achieve adequate perfusion (monitor for fluid overload)
- Continuous SpO_2, heart rate and respiratory rate monitoring
- BiPAP is the first-line recommendation for non-invasive respiratory support for patients with severe work of breathing and/or impending respiratory failure (BCCH/VGH PICU can support)
  - ⚠ Caution using HFNC: see considerations for potential use of HFNC in 'Oxygen and Respiratory Support' section of guideline
- Consult local pediatrician on-call; if no pediatrician call CHARLiE via ZOOM/phone and PICU/higher level of care center via PTN
- Consider intubation with PICU consult in patient with impending respiratory failure despite maximum therapy

Consider:

- CXR
- Blood gas (venous, capillary or arterial)
- Electrolytes, CBC & Differential
- POC blood glucose
- Possibility of a pneumothorax
- Anesthesia consult for airway management

REASSESS PRAM SCORE EVERY 15 MINUTES OR AS DIRECTED

MILD: Score 0 to 3 or MODERATE: Score 4 to 7

Reassess vital signs and PRAM q 30 min x 2 (salbutamol 1 dose q 30 to 60 minutes); then

Move to **MILD** or **MODERATE** management (page 1)

SEVERE: Score 8 to 12

- Continuous administration of nebulized salbutamol
- Early consultation with BCCH/VGH PICU via PTN for all patients with:
  - impending respiratory failure,
  - those who fail to improve following initial management; **and/or**
  - in patients for whom transfer to a higher level of care is anticipated
- Continue assessments q 15 minutes or as otherwise directed

Asthma – In a hurry – Management PRAM 8-12

Algorithm: Initial Management of Pediatric Asthma Exacerbations (Page 2 of 3)

Start timing for reassessment and next dose when medication administration **starts** (1^{st} puff/nebulization begins)

SEVERE: Score 8 to 12

- Inhaled salbutamol and ipratropium MDI with spacer or nebulizer q 20 minutes (3 total doses)
  - If salbutamol q 20 minutes x 3 already provided, administer continuous nebulized salbutamol
  - If ipratropium already provided during management, do not administer again
- Establish vascular access
- If not already provided, administer:
  - MethylPREDNISolone IV, even if PO steroid already provided
- Continuous SpO_2, heart rate and respiratory rate monitoring
- Most responsible physician at bedside, consult RRT (if available)
- Consider early respiratory support and magnesium sulfate infusion (see below for further recommendations)
- Consult local pediatrician on-call; if no pediatrician call CHARLiE via ZOOM/phone and a higher level of care center via PTN
- Rural/remote sites consider/prepare transfer to higher level of care

REASSESS PRAM SCORE 1 HOUR AFTER INITIATING TREATMENT

MILD: Score 0 to 3 or **MODERATE:** Score 4 to 7

SEVERE: Score 8 to 12

- Begin of maintain continuous administration of nebulized salbutamol
- If not already provided, adminster:
  - MethylPREDNISolone IV (even if PO steroid already provided)

Consider:
- CXR

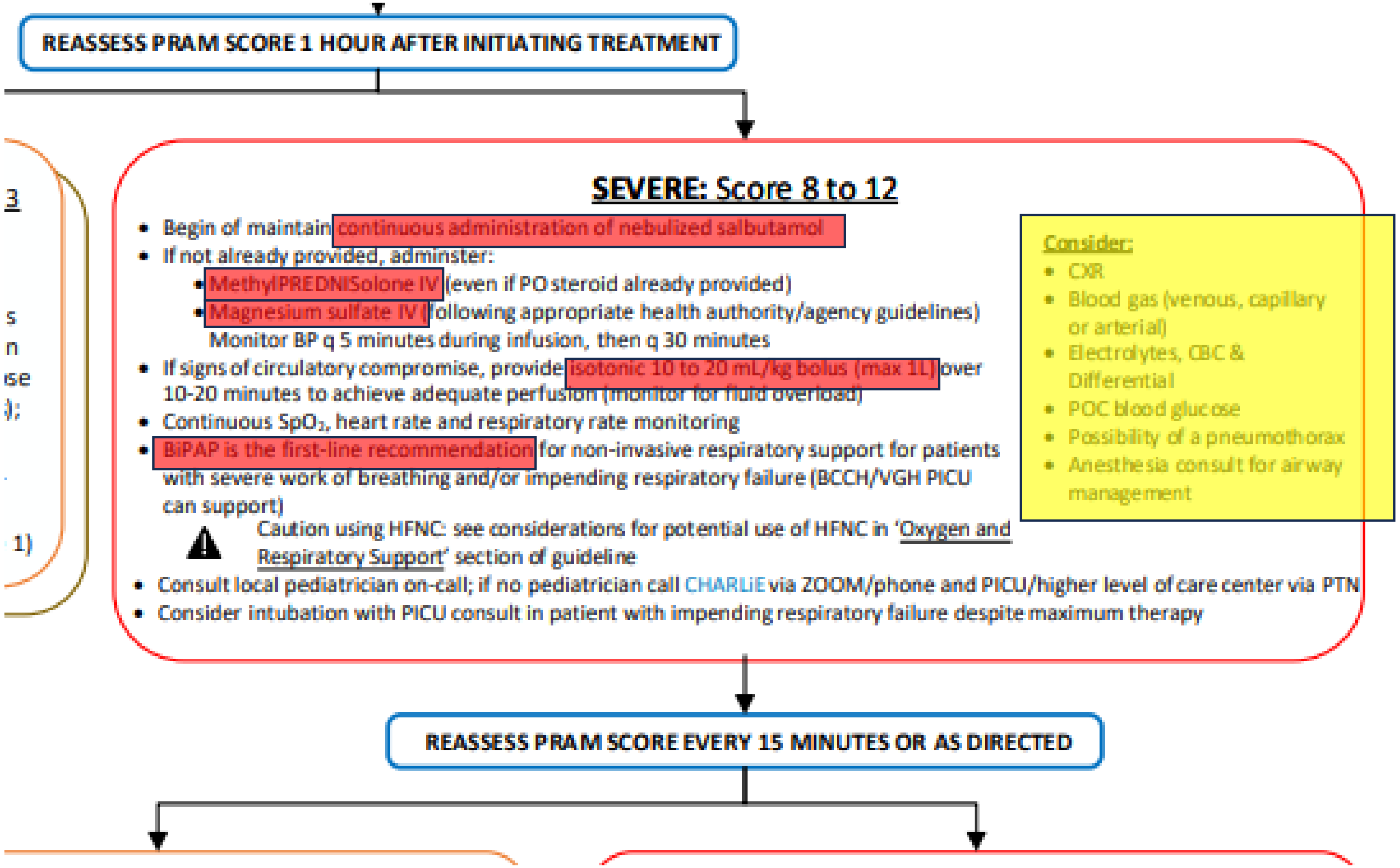
Refer to: Provincial Pediatric Asthma Guideline for detailed instructions on intervention and care.

See Medication Reference Table below (p.3) for doses and list of abbreviations

Signs of Impending Respiratory Failure

- Decreased level of consciousness
- Agitation
- Cyanosis
- Decreased respiratory effort
- Confusion

Asthma – In a hurry – Management PRAM 8-12



Asthma – In a hurry – Management PRAM 8-12

REASSESS PRAM SCORE EVERY 15 MINUTES OR AS DIRECTED

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SEVERE: Score 8 to 12

- Continuous administration of nebulized salbutamol
- Early consultation with BCCH/VGH PICH via PTN for all patients with:
    - impending respiratory failure,
    - those who fail to improve following initial management; **and/or**
    - in patients for whom transfer to a higher level of care is anticipated
- Continue assessments q 15 minutes or as otherwise directed

Algorithm: Initial Management of Pediatric Asthma Exacerbations (Page 1 of 3)

Start timing for reassessment and next dose when medication administration **starts** (1st puff/nebulization begins)

INITIAL Management

Known or suspected asthma exacerbation AND age 1 to 16.99 years

Refer to: Provincial Pediatric Asthma Guideline **for detailed instructions on intervention and care.**

See Medication Reference Table **below (p.3) for doses and list of abbreviations**

CALCULATE PRAM SCORE AND IMMEDIATELY BEGIN TREATMENT

MILD: Score 0 to 3

- Oxygen to maintain SpO_2 92% or more
- Salbutamol 1 dose q 20 minutes via MDI with spacer (max 2 doses within the first hour)
- Reassess PRAM score 20 minutes after initial salbutamol administration:
  - **Mild 0 to 3:** Move to next box of mild management below
  - **Mod. 4 to 7:** Move to start of moderate management
  - **Severe 8 to 12**: Move to start of severe management (page 2)

MODERATE: Score 4 to 7

- Notify MRP and RRT consult (if available)
- Salbutamol q 20 minutes (3 total doses) via MDI with spacer
- Ipratropium q 20 minutes (3 total doses), deliver in **the first hour of treatment only**, via MDI with spacer
- Oral corticosteroid immediately after the first dose of salbutamol/ipratropium
- Oxygen to maintain SpO_2 92% or more
- Non-emergent care settings, consider transfer to higher level of care

SEVERE: Score 8 to 12

NOTIFY MRP IMMEDIATELY AND MOVE TO SEVERE MANAGEMENT (page 2)

REASSESS PRAM SCORE AND VITAL SIGNS 1 HOUR AFTER INITIATING TREATMENT

Case #3 continued

- You have appropriately identified that this child is in impending respiratory failure and have elected to start BiPAP in the ED and consult PICU.

- The medical student points out that the patient is already hyperinflated, won't BiPAP make him worse?

BiPAP and asthma exacerbation

- Delta P = decreases work of breathing
- Hyperinflation = positive pressure in the alveoli
  - PEEP: positive pressure in the airway =
    - Decreases the amount of work necessary to initiate inspiration
    - Stent airways open = helps exhalation
    - Stent alveoli open = helps with V/Q mismatch

Status asthmaticus management

- Advanced therapies
  - IV steroids
  - IV magnesium sulfate (max 75mg/kg total)
  - Continuous salbutamol nebs vs IV infusion
  - Ketamine
  - Inhaled anesthetics
  - Heliox
  - Aminophylline

NON INVASIVE POSITIVE PRESSURE VENTILATION (NIPPV)

Equipment

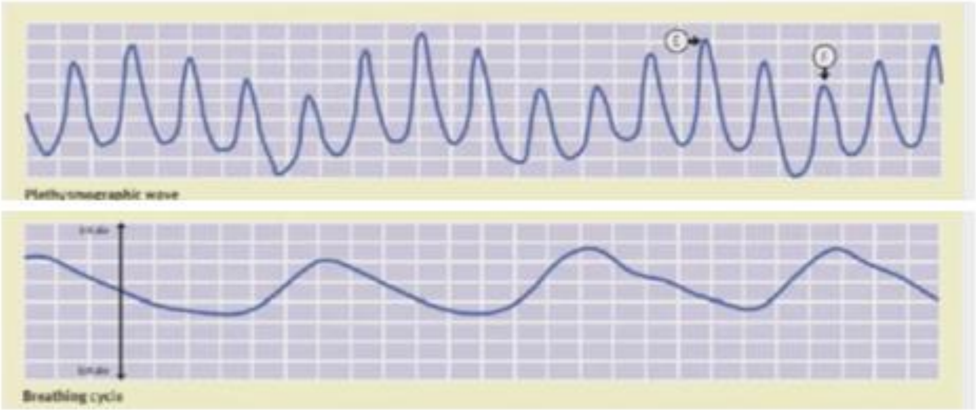
Set Up & Management

Settings on BiPAP

Medication Administration

Case #3 continued

- Unfortunately, the patient has continued to deteriorate and now has an almost silent chest and is very somnolent.
  - Repeat gas: pH 7.05 CO_2 73 lactate 7.5
  - VS: HR 150, BP
- You make the decision to intubate this patient
  - Anticipated complications on intubation?
  - Explanations for shock and lactic acidosis
  - Initial settings on ventilator?



Status asthmatic and shock

- Dehydration = decreased pre-load
- Tachycardia = decreased diastolic RV/LV filling = decreased pre-load
- Effects of positive intra-thoracic pressure / obstructive physiology = affects both pre-load and afterload (next slide)
- Severe acidosis = can affect contractility + risk of arrhythmias

- Salbutamol (B-adrenergic) also causes hyperglycemia and hyperlactatemia

Ventilator settings

Setting	Volume limited mode	Pressure limited mode
Volume or pressure	Set tidal volume (V_T) of; 6-8 ml/kg for children 4-6 ml/kg for neonates	Start at peak inspiratory pressure of 18-20 H_2O. Titrate to chest movement and V_T <10ml/kg
Inspiratory time	Infants: 0.5-0.6 seconds Toddlers: 0.6-0.8 seconds Older children and adolescents: 0.8-1.2 seconds	
Respiratory Rate	Infants: 30-40/min Toddlers: 25-35/min Pre-school aged children: 20-30/min School aged children: 15-25/min Adolescents: 10-20/min	
Pressure support	6-12 cm H_2O	
PEEP	5-8 cm H_2O	

Low respiratory rate
Maximize eTime
"Optimal PEEP"
Permissive hypercapnia

Case #4

- 2 year old girl admitted to the ward for Influenza A pneumonia 2 days ago. Was initially on LFNC 1-2L/min but over the night escalated to HFNC 2L/kg/min with FiO_2 up to 80% to maintain sats of 90%. Progressive increase in work of breathing.
  - VS: HR 120, RR 40, Sat 89%, BP 80/35
  - Gas : 7.25 – 71 – 31 BE -2 Lactate 2.5

Worried?
Dx?
Immediate management?

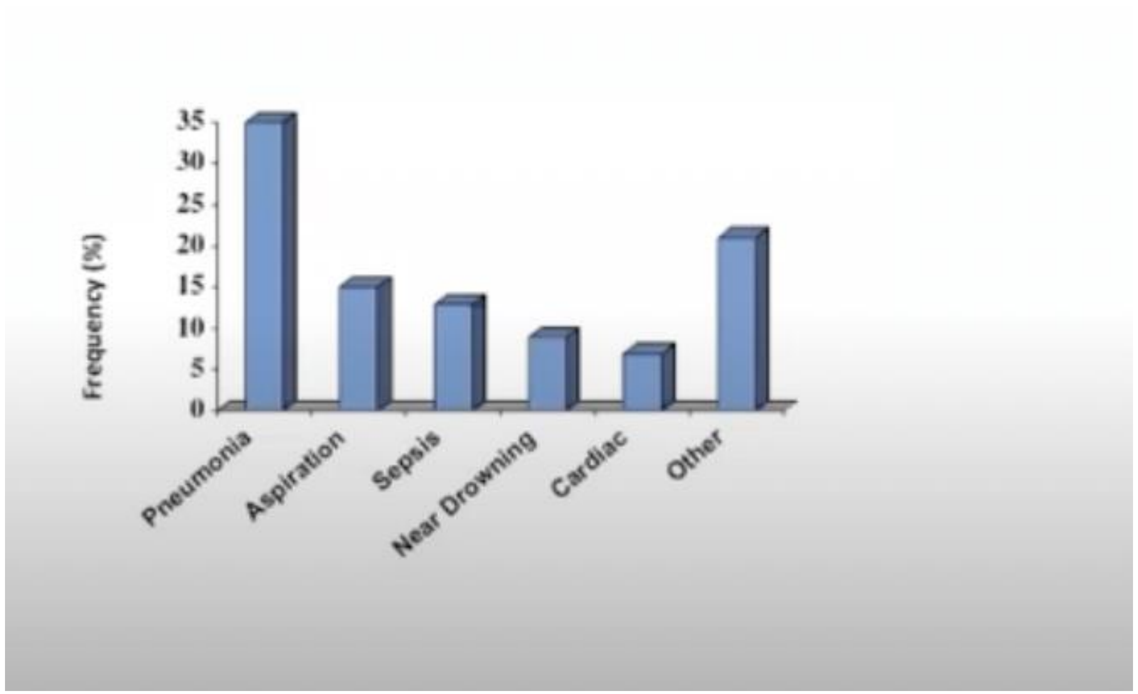
pARDS - Definition

Age	Exclude patients with perinatal lung disease
Timing	Within 7 days of known clinical insult
Origin of Edema	Not fully explained by cardiac failure or fluid overload
Oxygenation	IMV: OI $\geq$ 4 or OSI $\geq$ 5 NIV: PaO2/FiO2 $\leq$ 300 or SpO2/FiO2 $\leq$ 250
CHD/CLD	Acute deterioration not explained by congenital heart disease or chronic lung disease

PALICC-2 2023

Oxygenation Index (OI)= MAP/PaO2
Oxygen saturation index (OSI)= MAP/SatO2
Saturation Fraction (SF) = SatO2/FiO2

pARDS-causes



Fiori et al, AJRCCM 2005

Direct

- **Pneumonia**
- Aspiration
- Near drowning
- Inhalation
- Traumatic

Indirect

- Sepsis
- TRALI
- Multi-trauma

Clinical Presentation

- Rapidly evolving
- Hypoxia
- Respiratory distress
- Hypocarbia then hypercarbia

CXR : diffuse infiltrates, air bronchograms, effusions, atelectasis

Case # 4 continued

- You were appropriately worried about this patient and decided to intubate.
- What are your initial ventilation settings?

Management of ARDS

- Lung-protective ventilation
  - Vt 6-8* ml/kg
  - Moderate PEEP 10-15 titrated to oxygenation/HD
  - Permissive hypercapnia (pH>7.20)
  - Pressure limits
    - Peak : $\leq$ 32
    - Plateau: $\leq$28 or <=32 if reduced chest wall compliance
    - Driving: ≤ 15

- Adjunct therapies (limited evidence)
  - **Fluid restriction / diuretics**
  - **Sedation and paralysis**
  - **Prone positioning**
  - **Antibiotics**
  - iNO (pHTN, RV dysfunction)
  - Steroids
  - Surfactant
  - pRBCs

* Adjust Vt down to 4-6 ml/Kg if > PIP or > DP limits

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Questions on anything concerning respiratory failure