Basics of Pediatric Ventilation

March 2025 update

Objectives

1. Introduction to Respiratory Support of the Pediatric Patient
    - Types of ventilatory support
    - Low flow and high flow
2. Non-Invasive Ventilation
    - Interfaces
    - Settings and modes
    - Initiation and management
3. Invasive Ventilation
    - Pre/post extubation considerations
    - Settings and modes
    - Initiation and management

Introduction to Respiratory Support of the Pediatric Patient

Types of respiratory support

1. Low Flow Oxygen Therapy (LF)
2. Heated and Humidified High Flow Oxygen Therapy (HF)
3. Non-Invasive Ventilation (NIV)
    - Continuous Positive Airway Pressure (CPAP)
    - Bi-Level Positive Airway Pressure (BiPAP)
4. Invasive Ventilation

Provincial Health Services Authority · BC Children's Hospital · Child Health BC · Pediatric Critical Care · StEP Stabilization Essentials in Pediatrics

Low Flow Oxygen Therapy

Conventional prediction model: 1 L/min = increase in FiO_2 by 4% above RA

- Prediction formula based on adult inspiratory flows
- Pediatrics have lower inspiratory flows varying with age/size
  - Consider LF in peds using minute ventilation
    - MV = 100-200mL/min/kg
    - In this context, LF delivers a significantly higher FiO_2 to peds than adults
    - If approaching 3-4L/min, consider escalation of support

Heated and Humidified High Flow O2

Goal is to deliver adequate flow to meet or exceed the patient's inspiratory flow demand:

- Establishes control of FiO_2 delivery (as not diluting with room air)
- Reduce WOB by supporting inspiratory flow demand
- Humidification to optimize secretion clearance
- Reduction of dead space (enhances upper airway clearance reducing rebreathing of CO_2)

Initial Flow Rate for HFNC Therapy is the same for all patients regardless of medical condition

- **≤12Kg: 2 L/kg/minute**
- **>12Kg: 2 L/kg/minute for the first 12kg + 0.5L/kg/minute for each kg thereafter (max flow 50 L/min)**

Increase flow to the prescribed rate over a few minutes, or as tolerated.

Interface, Circuit and Machine-Specific Flow Rate Ranges

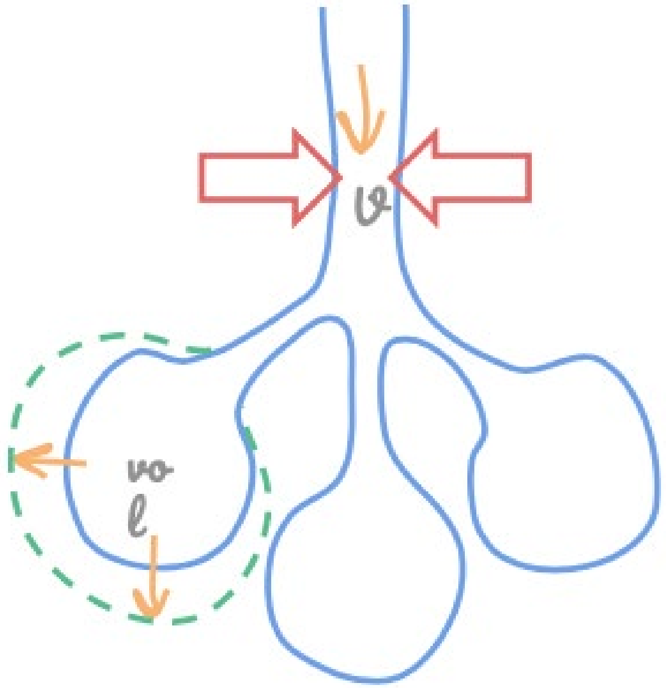
Interface Size	F&P Neo Circuit Flow Rate Range	F&P Adult Circuit Flow Rate Range	Airvo Mode	Flow Rate Range with Airvo 2
Premature (XS)	0.5 - 10 L/min	1 - 10 L/min	N/A	-
Neonatal (S)	0.5 - 10 L/min	1 - 10 L/min	N/A	-
Infant (M)	0.5 - 11 L/min	1 - 11 L/min	N/A	-
Intermediate Infant (L)	0.5 - 34 L/min	1 - 34 L/min	Junior	2 - 20 L/min
Pediatric (XL)	0.5 - 36 L/min	1 - 36 L/min	Junior	2 - 25 L/min
Pediatric (XXL)	0.5 – 60 L/min	1 – 60 L/min	Adult	10 - 50 L/min
Small	N/A	10 - 50 L/min	Adult	10 - 50 L/min
Medium	N/A	10 - 60 L/min	Adult	10 - 60 L/min
Large	N/A	10 - 60 L/min	Adult	10 - 60 L/min

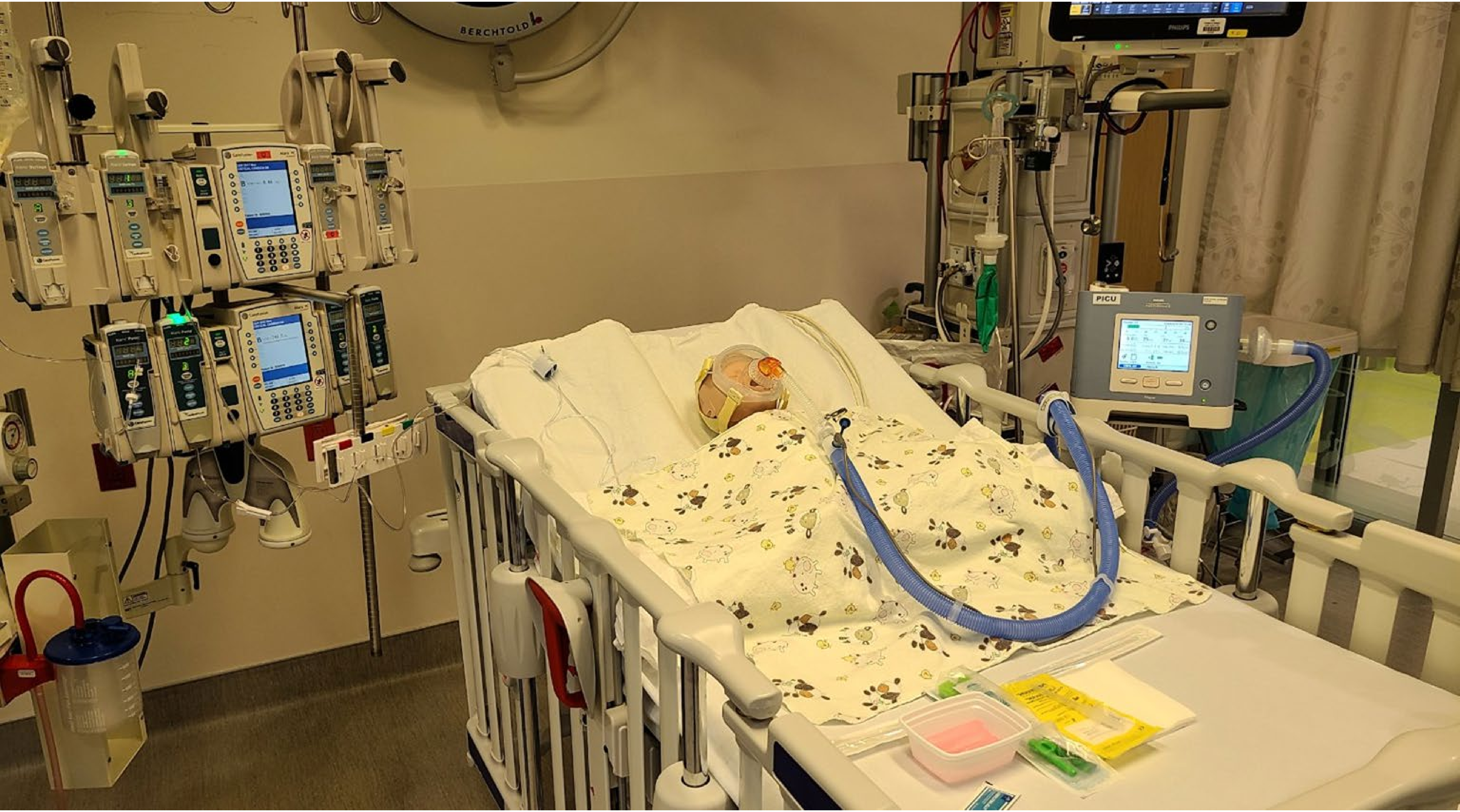
Non-Invasive Ventilation

Positive Pressure Ventilation

Common pediatric disease processes that challenge airway resistance and lung compliance

- Resistance
  - Obstructive disease processes: decreased airflow on expiration
  - Asthma
  - Bronchiolitis
  - Airway anomalies (laryngo/tracheomalacia)
  - UAO: croup, epiglottitis
- Compliance
  - Restrictive disease processes: compromised lung volume
  - Atelectasis/consolidation
  - Bronchiolitis
  - Aspiration/bacterial/viral pneumonia
  - pARDS
  - CHF




BERCHTOLD
PHILIPS
PICU

Non-invasive PPV (NIV or BiPAP)

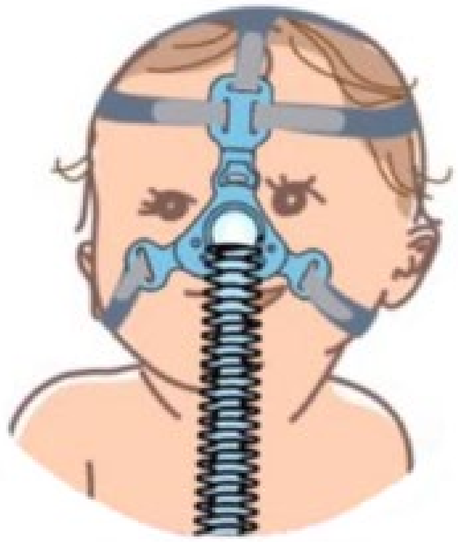
Delivery of positive pressure ventilation

- Application of positive pressure at airway opening to promote flow into the lungs to promote effective gas exchange
  - Without use of an artificial airway (endotracheal tube or tracheostomy tube)
  - Instead, via interface such as a face or nasal mask

Use of NIV is markedly increasing

- In both acute and chronic pediatric respiratory patients

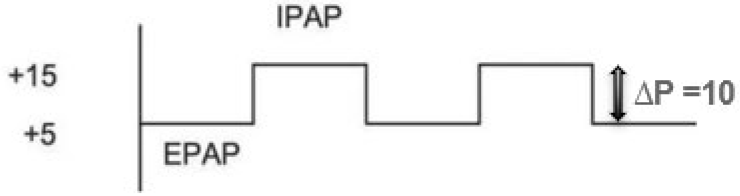
Available Interfaces



Total face mask (Performax) Mask

Full Face

Terminology on BiPAP



BiPAP is defined as the application of two positive airway pressures

Different ventilators use different nomenclature, so it is vital to be aware of the ventilator you are using and the nomenclature associated with the pressure delivery

- Adjusting to achieve adequate Vt or chest rise, CO_2 clearance , patient comfort
- IPAP is set independently of EPAP
- Interchangeable terminology: peak pressure or total/absolute pressure

- **ΔP** (Pressure Gradient) = IPAP – EPAP
  - IPAP of 15 cmH_2O and EPAP of 5 cmH_2O offers a pressure gradient (ΔP) of 10 cmH_2O

Review Date: Mar 08 2025

Settings on BiPAP: Modes

Pressure targeted modes

- Spontaneous: primary mode of choice
- Controlled mode: mean airway pressure with set Ti promotes recruitment
- Consider preparing for intubation:
  - Persistent ventilation/oxygenation issues despite
    - High BiPAP settings (e.g. IPAP/EPAP =18/10)
    - High FiO_2 requirements
    - Repositioning and suctioning

Hamilton T1: Common BiPAP modes/settings

- NIV (noninvasive ventilation)
  - Every breath is spontaneous
  - Settings: ΔPsupport + PEEP/CPAP
  - e.g ΔPsupport 6 cmH_2O+ PEEP/CPAP 6 cmH_2O= total inspiratory pressure 12 cmH_2O

- NIV-ST (spontaneous/timed non invasive ventilation)
  - Every breath is spontaneous as long as the patient is breathing above the set rate. A back up rate can be set for mandatory breath
  - Settings: ΔPinsp +PEEP/CPAP, RR
  - e.g ΔPinsp 8 cmH_2O+ PEEP/CPAP 8 cmH_2O = total inspiratory pressure 16 cmH_2O

Trilogy: Common BiPAP modes/settings

- S (**S**pontaneous)
    - Every breath is spontaneous
    - Settings: IPAP, EPAP
    - e.g IPAP 12 cmH_2O/EPAP 6 cmH_2O gives ΔP=6 cmH_2O
- S/T (**S**pontaneous/**T**imed)
    - Every breath is spontaneous as long as the patient is breathing above the set rate. A back up rate can be set for mandatory breath
    - Settings: IPAP, EPAP, RR
    - e.g IPAP 18 cmH_2O /EPAP 8 cmH_2O gives ΔP=10 cmH_2O

- The setting on the most of home machines is IPAP/EPAP

Case: 4mo, 7kg Male with Bronchiolitis

- 4mo, 7kg Male admitted with bronchiolitis 2° Entero/Rhinovirus
- Escalated from HFNC 15LPM 40% O_2 to NIV 12/6 40%
- Minimal improvement to WOB
  - Remains tachypneic RR 70s and tachycardic HR 150s
  - Moderate to severe subcostal indrawing and tracheal tug, nasal flaring

What are the next steps in this patient's management

Escalation of care

For the acutely ill child who is previously healthy

- Determining which setting to address: IPAP, EPAP, both, and/or mode

- Optimize FRC by increasing PEEP, optimize Vt by increasing ΔP or IPAP (absolute pressure)
    - A safe escalation of pressure would be to increase ΔP or IPAP by 2 cmH_2O each time, and increase PEEP/EPAP by 1-2 cmH_2O

- Common examples of increasing BiPAP settings: (IPAP/EPAP in cmH_2O)

  12/6 → 14/7 → 16/8 → 18/8 → 18/10 → 20/10 → 20/12

    - Max IPAP likely to be 20 cmH_2O before considering more advanced therapy such as intubation
    - Not due to concern about damaging the lungs as that pressure is 30 cmH_2O
    - But due to potential opening pressure of the esophagus which is estimated to be 20 cmH_2O
        - Recommendation: NG tube

Escalation of care

- Optimize airway patency via positioning, airway suctioning (oropharyngeal, nasopharyngeal), medication such as Ventolin via MDI + spacer (preferrable) or mesh nebulization (aerogen), or prone position

- Optimize patient comfort
  - Sedation may be required
  - NG tube placement prior to initiation reduces gastric distension
  - Optimize settings for patient comfort/confirm each breath is triggered and delivered

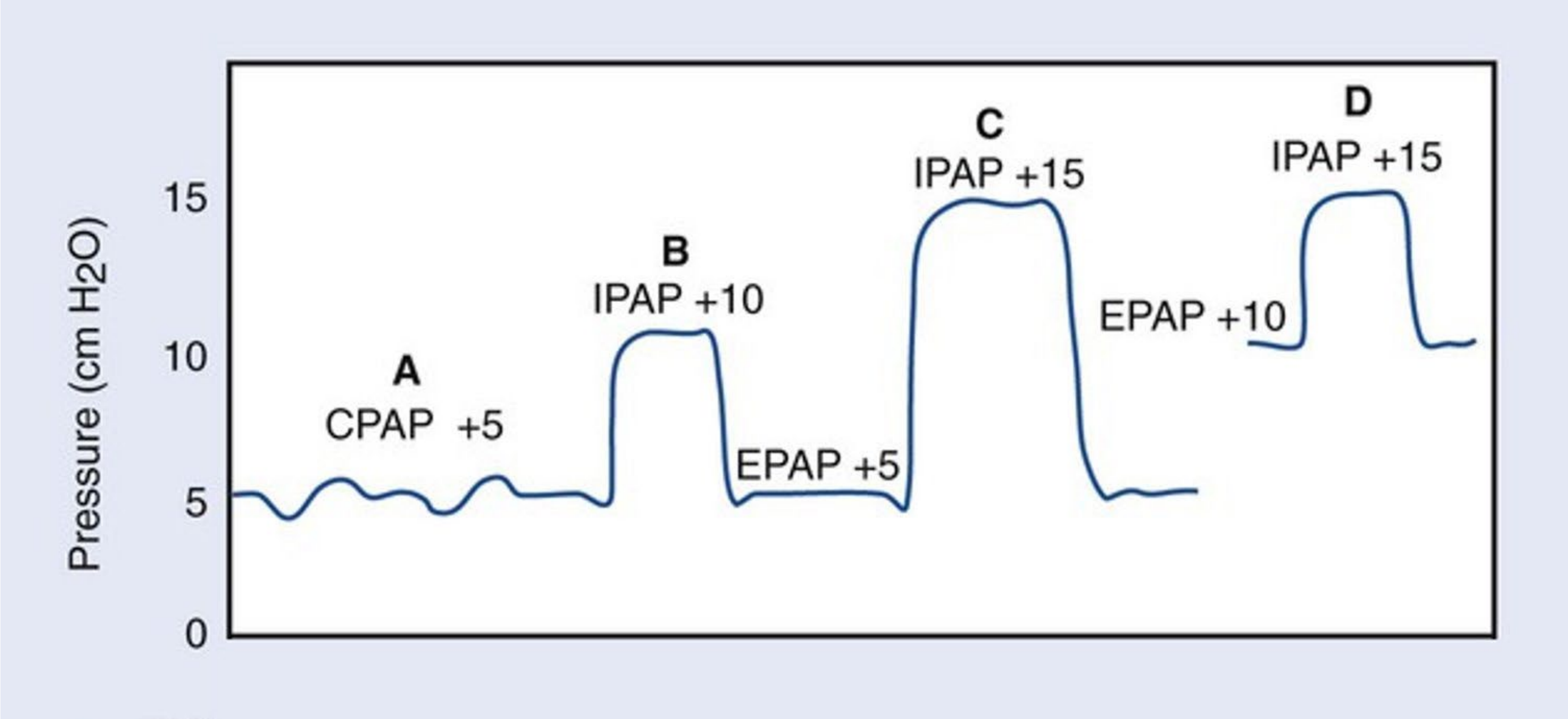
- Guided by clinical assessment and disease process
  - Patient assessment: WOB, RR, chest rise, auscultation, SpO_2
  - Disease Process: compliance, resistance, or both?
  - CXR: atelectasis, consolidation, homogenous, heterogenous
  - ABG: $PaCO_2$, PaO_2, SaO_2
  - Delivered Vt

Escalation of care

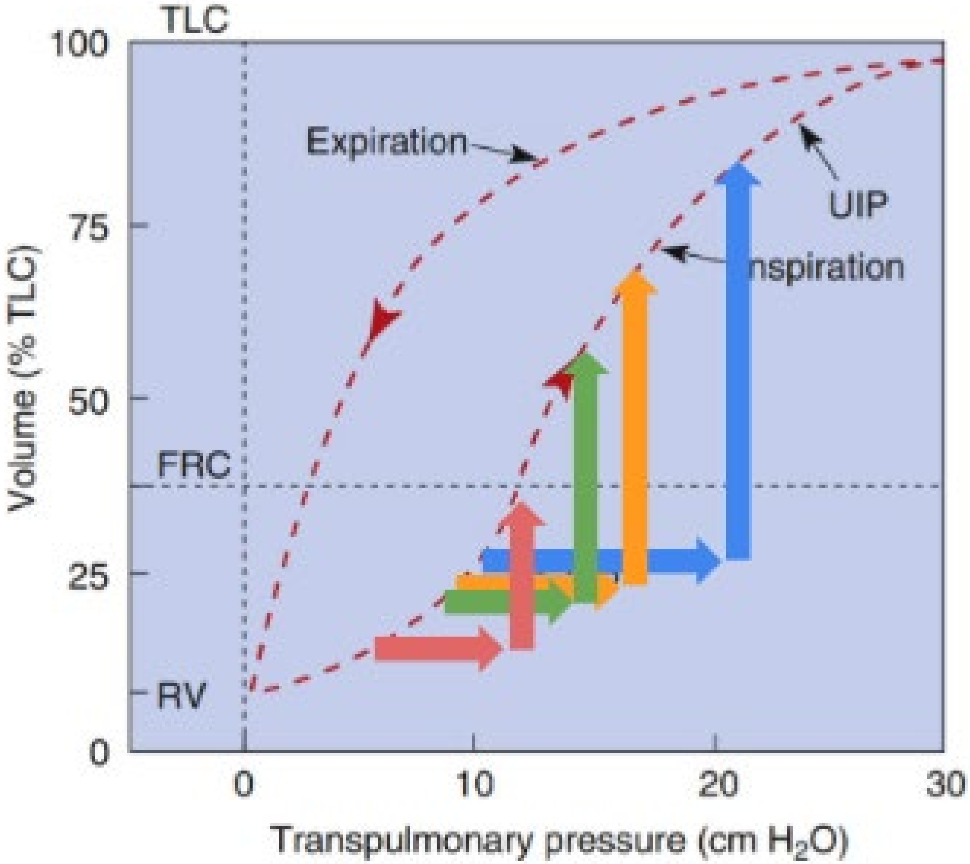
For the child on home BiPAP with an acute illness

- These patients typically have nasal masks (safety) and if arriving ill, the first option may be to change interface to a full or total face mask to optimize ventilation
- Otherwise, can increase patient's "home settings", add/increase FiO_2 and other adjuncts as above

Titration of Pressures



Titration of Pressures



- ❑ 12/6
- ❑ 14/7
- ❑ 16/8
- ❑ 20/10

Management of BiPAP

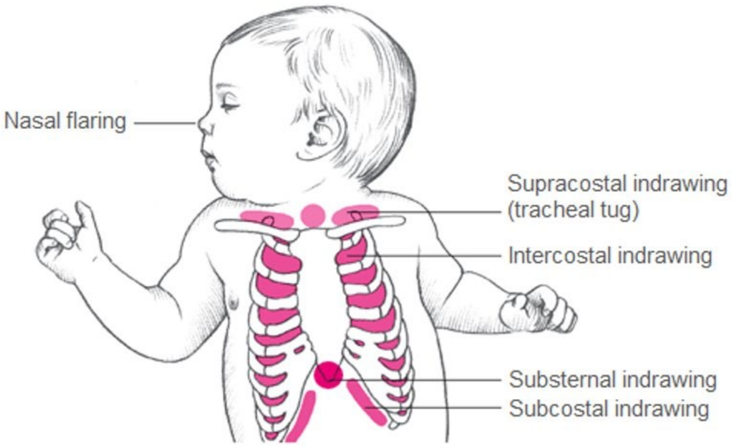
Considerations when managing / maintaining a patient on BiPAP:

- Adequate sedation
- Assess effectiveness of BiPAP
    - Clinical presentation: WOB, RR, SpO_2, HR
    - Assess mask seal/leak
    - Critical to optimize ability of patient to trigger a breath
- Clinical pearl: compare monitored RR on vent to that from ECG leads
- Perform face care
    - Skin breakdown and pressure sores
    - Q4H if tolerated, if unstable then PRN
    - Suction: oropharyngeal and nasopharyngeal
- If unstable BiPAP, anticipate trajectory towards potential intubation

Weaning of BiPAP

1. Wean pressures as tolerated based on improved WOB, vitals, blood gases
2. Once pressures have been weaned to comfortable settings (ie 12/6, 14/7, or for some 16/8), consider trials off
   - This decision can often be guided during face care
   - Face care involves: wiping of face, assessing skin breakdown, oropharyngeal and nasopharyngeal suctioning, mouth care
   - Take this opportunity to clinically assess how patient is tolerating time off of BiPAP
   - Increased WOB? RR? HR? Decreased SpO_2?
3. If patient remains comfortable and stable, trial off for as long as tolerated
   - May transition to low flow nasal cannula or even to room air
4. If after period of time patient no longer tolerating time off support, place back on BiPAP and trial off again at a later time

For HTV patients, goal is to wean back to home settings
(interface and ventilatory pressures) and home routine (ie: nights and naps)



Invasive Ventilation

BCCH PRE-INTUBATION TIMEOUT CHECKLIST

Is a difficult airway anticipated? If YES, CALL ANESTHESIA.

PATIENT PREPARED?

- **Nasal cannulae applied**
  - **< 1 year 5LPM**
  - **1-7 years 10LPM**
  - **>7 years 15LPM**
- **Functioning IV/IO?**
- **Patient exposed?**
- **Patient position optimized?**
- **Patient pre-oxygenated?**
- **Patient hemodynamics optimized?**
- **Does patient airway assessment identify any concerns?**
- **Failed intubation backup plan?**

EQUIPMENT READY?

- Suction
  - Yankauer/oral suction prepared with regulator turned to max
- Oxygen
  - Mask
  - self inflating bag-valve
  - JR flow inflating system
- Airway equipment
  - working laryngoscope /blade
  - ETT plus 0.5 smaller size
  - lubricated stylet
  - oral airways/NPA
  - LMA
  - Videolaryngoscope available?
- Pharmacologic agents
  - induction/paralytic drugs
  - fluids / vasopressor?
- Monitoring Equipment
  - SaO_2
  - ECG
  - BP
  - Waveform $ETCO_2$

TEAM READY?

- **Gown, glove and eye protection**
- **Team members introduced**
- **Team leader identified**
- **RT/intubator checked equipment**
- **Nurse to administer medications**
- **Anticipated problems identified – anyone have questions or concerns?**
- **Identify recorder/capture "event start" on bedside Philips monitor**

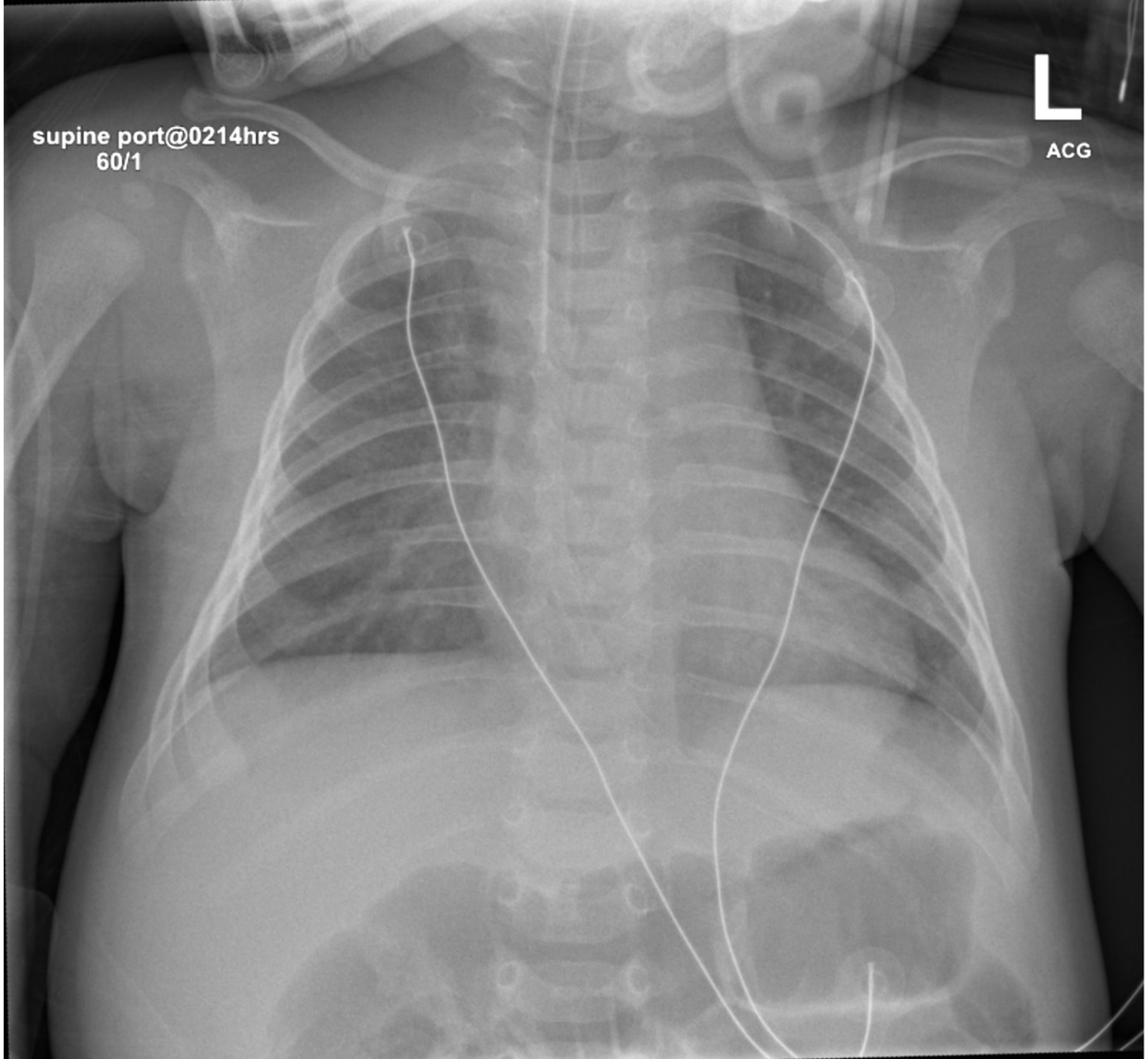
PLAN FOR CONSEQUENCES

- **Successful intubation?**
  - secure ETT
  - CXR
  - ongoing sedation / paralysis
  - ventilation parameters set
- **Document procedure in medical record**
- **Complete NEAR4KIDS audit record**
- **RT to complete NEAR4KIDS blue sheet**

ETT Size and Depth

ETT Size:
- 3.0-3.5 ETT for < 1 year old
- 3.5-4.0 ETT for < 2 years old
- For $\geq$ 2 years old:
  - Cuffed ETT = age/4 + 3.5
  - Uncuffed ETT = age/4 + 4
    - *uncuffed ETT is preferred for suspected croup*

ETT Depth:
- PALS estimation for > 1 year: [age (in years)/2] + 12
- ID estimation (for ETT $\geq$ 3.0): ID of ETT x 3
- Add 2-3 cm for nasal intubations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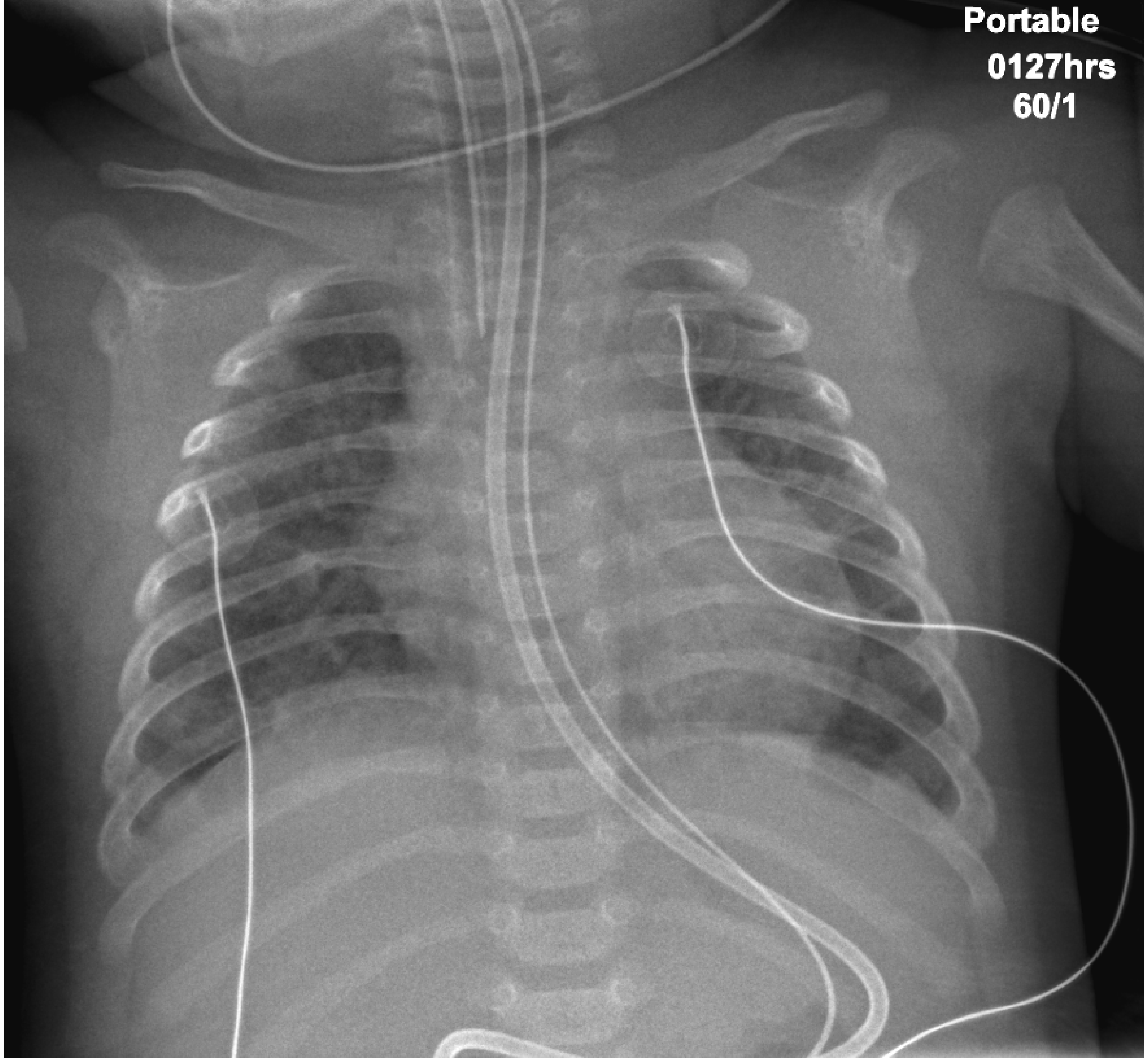


Pediatric Critical Care
OUTREACH EDUCATION FOLLOW-UP INITIATIVE

StEP Stabilization Essentials in Pediatrics

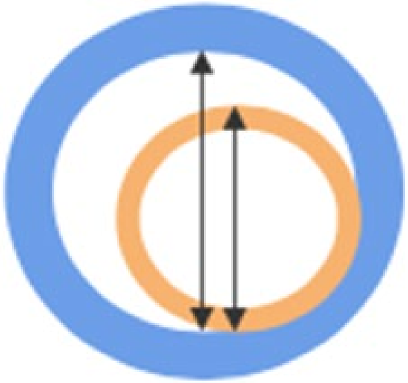
Provincial Health Services Authority
Province-wide solutions. Better health.

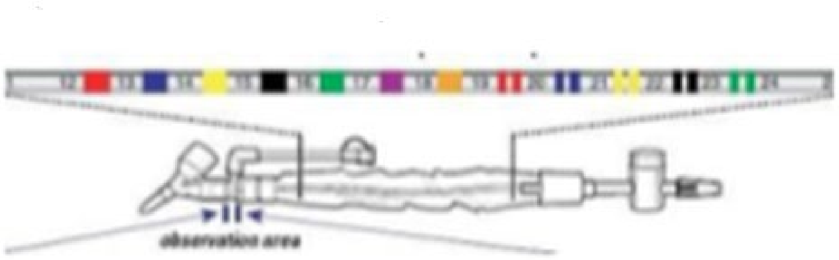
BC Children's Hospital

Child Health BC

StEP Stabilization Essentials in Pediatrics

Suction Catheters





ETT: inner diameter in mm

Suction Catheters: outer diameter in Fr

- Would like a suction catheter that occludes ~2/3rd of the ETT ID
  - ~~1mm = 3Fr~~
  - ~~Multiply the ETT size (ID) by 3 to find a suction catheter that will occlude 100% of the ETT. Multiply that by 2/3 to acquire the appropriate suction catheter~~
  - ~~In short,~~ **ETT size x 2 = appropriate sxn catheter size in Fr**
- ***note: safe suction depth in neo/ped pt = 0.5cm past end of ETT

~~Example:~~
~~4.0 ETT~~
~~4 x 3 = 12F~~
~~12F x 2/3 = 8F~~

Initiation of Ventilation

Selecting mode of ventilation:

- Choose the mode you are most comfortable with

Pressure Target Modes:

- Pressure Control:
  - PC above PEEP, Ti
- Pressure Support:
  - PS above PEEP, flow cycle

Volume Target Modes:

- Volume Control:
  - Target volume via set flow
- Pressure Regulated Volume Control:
  - Target volume with ventilator dictated PC, Ti
- Volume Support:
  - Target volume with ventilator dicated PS above PEEP, flow cycle

Ventilation parameters and target

	PICU	NICU
***Vt	6 - 8 mL/kg	4 - 6 mL/kg
RR	10 - 30	40 - 60
Ti	0.5 - 1.2	0.35 - 0.55
PEEP	5 - 10	5 - 8
MV	100-200 (mL/min/kg)	200-300 (mL/min/kg)

***IBW is reflected by actual body weight (unless pt is obese)
APLS estimation for (for 1-10yo): **Weight = (Age + 4) x 2**

	PICU	NICU
pH	7.35 - 7.45	7.25 - 7.45
pCO2	35 - 45	45 - 55
pO2	80 - 100	50 - 80
Bicarb	22 - 26	22 - 26
BE/BD	0 ± 2	0 ± 2
SpO2	≥95	<36wk = 88-92 ≥36wk = 90-95

Initiation of Ventilation

Age	<1 month	1 mo – 1 yr	1 - 3 yrs	4 - 5 yrs	6 - 10 yrs	> 10 yrs
Target MV (ml/min/kg)	200	175	150	125	125	100
Vt (ml/kg)	6-7	6-8	6-8	6-8	6-8	6-8
RR (br/min)	30 - 35	25-35	20-26	18-24	16-22	14-20
Ti (sec)	0.6	0.6-0.7	0.7-0.75	0.75-0.8	0.8-0.9	0.8-1.0

- When setting Vt, use the lesser of PBW/IBW or ABW
- Monitor and limit driving pressure &/or plateau pressure (plateau < 30cmH2O)
- If using lower Vt for lung protection, increase RR to maintain MV
- Pay attention to I:E ratio if increasing RR

Managing an I+V Pediatric Patient

- Support ventilation/oxygenation as per your discretion
  - May need to consider permissive hypoxemia/hypercapnia
- Optimize everything else
  - Suctioning***
  - Repositioning (proning etc)
  - Ventolin in context of reactive airways disease
  - Sedation/analgesia, muscle relation
  - NG tube to drain, feed

Managing an I+V Pediatric Patient

- Monitoring:
  - $EtCO_2$, SaO_2, RR, HR, BP
  - CXR, CBG/VBG/ABG
  - Ventilator synchrony, do waveforms support your diseases process (R vs C)
- I+V pediatrics are prone to:
  - R. mainstem intubation due to short trachea
  - Mucus plugs
  - Unplanned extubation
  - DOPE

Web Resources

Do you need quick access to resources to care for very sick children?

Access "In a Hurry" resources:

The Pediatric Critical Outreach Project is being led in collaboration by BC Children's Hospital PICU Team and Child Health BC with the vision to better support both the critically ill children while they are in their home community, as well as the clinicians who care for them.

Any questions or suggestions? Contact us at ped.critical.care.project@phsa.ca

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

← Pediatric Critical Care Home

RESOURCES IN A HURRY

Quick provider resources for life-threatening conditions

AIRWAY MANAGEMENT

Endotracheal Intubation

Respiratory Equipment

High Flow Nasal Cannula (HFNC)

- Equipment
- Set Up & Management
- Nasal Cannula Size & Prong Specific Flow Rate
- Troubleshooting
- Medication Administration

In-a-Hurry Summary

Non Invasive Positive Pressure Ventilation (NIPPV)

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

In-a-Hurry Summary

Mechanical Ventilator

- Ventilation Goals

In-a-Hurry Summary

Tracheostomy

- Tracheostomy Emergency Response
- Tracheostomy Tube Change

In-a-Hurry Summary

Suction

- Nasopharyngeal and Oropharyngeal Suctioning Video
- Endotracheal Tube Suctioning

In-a-Hurry Summary

References

BCCH Procedure:NON-INVASIVE POSITIVE PRESSURE VENTILATION: INITIATION AND MANAGEMENT AT BCCH

BCCH Guideline: Intubation in Pediatric Patients

BCCH Procedure: HIGH FLOW HUMIDIFIED NASAL PRONG OXYGEN THERAPY

Thank you for listening with bated breath!