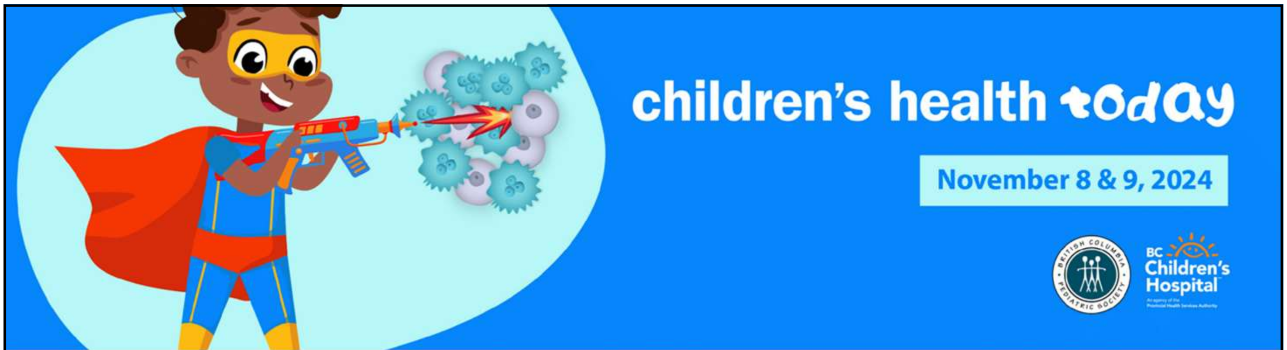


PICU Potpourri

Gaby Yang, MD, MSc, FRCPC, FAAP

Pediatric Intensivist, Victoria General Hospital, Island Health Authority

Clinical Assistant Professor, University of British Columbia

Objectives

- Discuss management approaches to common pediatric acute care cases
- Review of the role of non-invasive ventilatory support
- Discuss sedation strategies in the acute care setting.
- Overview of management approaches while waiting for transport to higher level of care.

Objectives

2 cases

- Non-invasive ventilation strategies
- Sedation strategies
- Fluid resuscitation strategies

Case 1a

- 8 weeks old (5kg) presents to ED
  - 3d URTI symptoms, decrease oral intake (slightly less wet diapers); no fever
  - 1d increased WOB.
  - 35 wga, uneventful perinatal history
  - No known sick contact
  - VS: HR 170, RR 63, BP 90/35, SpO2 88% RA, afebrile
  - Alert and crying ++.
  - Mild WOB: subcostal and intercostal retractions.
  - Chest diffusely coarse

Most likely diagnosis?

Bronchiolitis Management

- Hydration – oral, NG, IV
- Respiratory Support: Supplemental Oxygen +/- Ventilation

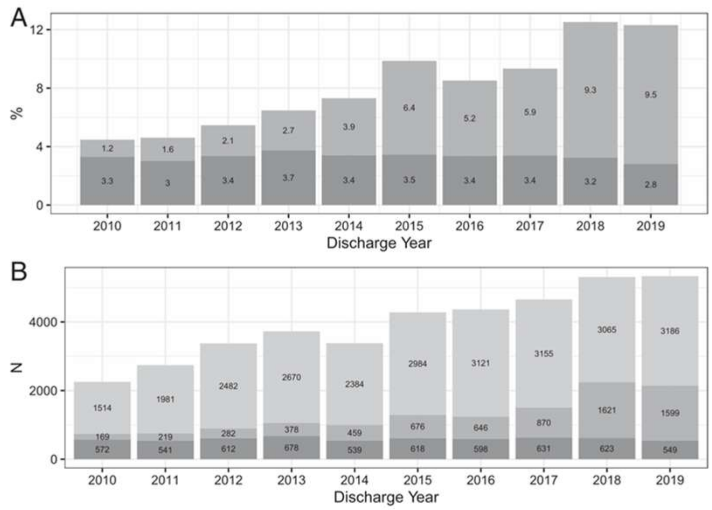


FIGURE 3
Changes in ventilatory support over time. A, the percentage of patients with bronchiolitis receiving noninvasive (light gray) and invasive (dark gray) ventilatory support. The y-axis represents percent of admissions, and the x-axis shows patients grouped by discharge year. Numbers within the bars represent the percentage. B, absolute numbers of invasive (dark gray), noninvasive (medium gray), and no (light gray) ventilatory support among patients admitted to the ICU. The y-axis shows absolute numbers, and the x-axis shows patients grouped by discharge year.

(Pelletier JH, et al. Pediatrics. 2021)

LFNP

- FiO2 variable, depends on:
  - Flow rate
  - Prong diameter
  - Patient's minute ventilation: *pediatric MV lower than adults, more FiO2 delivered*
  - Room air entrainment
  - Oxygen lost to environment

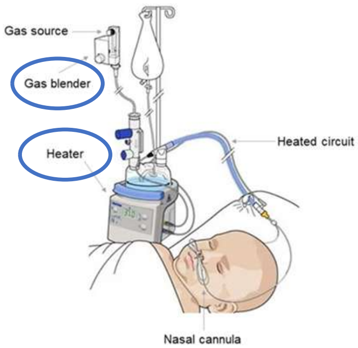
HFNP: High Flow Nasal Prong *(HHHF; HFNC)*

- Heated and Humidified mixture of gas (air and oxygen)
- Flow rate that meets or exceeds patient's peak inspiratory flow rate
  - Peak Inspiratory Flow Rate: variable with age/weight
    - 8-10x MV (infants 200 ml/kg/min adults 100 ml/kg/min)
    - Milesi *et al.* 2021: infant up to 6mo mean of 1.68 L/kg/min
  - Prevents room air entrainment accurate FiO2 delivery based on set O2%
- More efficient oxygen delivery device

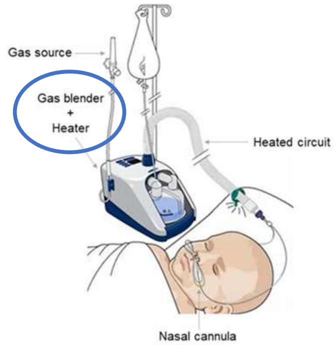
HFNP: *how does it work?*

- Reduces inflow of ambient air → improves oxygenation
- Washout of nasopharyngeal Dead Space → improved alveolar ventilation
  - Effective Alveolar Minute Ventilation = Actual ventilation – Dead Space Ventilation
  - Extra-thoracic dead space in children is 2-3x greater than adults
- Optimal gas conditioning / humidification → decrease WOB
  - Humidified air is *less* dense than dry air
- Distending Pressure/Positive Airway Pressure *(4? 6? #? cmH2O)* → decrease WOB + improve oxygenation
  - HF delivers steady gas flow; pressure will vary with respiratory mechanics

HFNP Set-Up



Optiflow



Airvo2

BCSRT
BC Society of Respiratory Therapists

Nasal cannula size and prong specific flow rates

Patient Weight	Estimated Nasal Prong Size	Prong Flow Rate with Optiflow (min - max)	F&P Mode	Prong Flow Rate with Airvo (min - max)
0.5 - 2.5 kg	Premature (XS)	0.5 - 8 L/min	Junior	-
0.9 - 4 kg	Neonatal (S)	0.5 - 9 L/min	Junior	-
1 - 10 kg	Infant (M)	0.5 - 10 L/min	Junior	-
3 - 20 kg	Intermediate Infant (L)	0.5 - 23 L/min	Junior	2 - 20 L/min
5 - 22 kg	Pediatric (XL)	0.5 - 25 L/min	Junior	2 - 25 L/min
> 22 kg	Small	10 - 50 L/min	Adult	10 - 50 L/min
> 22 kg	Medium	10 - 60 L/min	Adult	10 - 60 L/min
> 22 kg	Large	10 - 60 L/min	Adult	10 - 60 L/min

Note: When increasing the flowrate over 25 L/min, RRT to gradually increase flowrate over two minutes and observe how the change is tolerated.

HFNP dose: *more is not necessarily better…*

≈ 2 L/kg/min

(flow ≥ peak inspiratory flow rate)

- *CO2 clearance and RR: no difference with higher flows*
- *Airway Pressure and WOB: better at higher flows (2-3 L/kg/min) in neonates*

Weight	Flow Rate
0-12 kg	2 L/kg/min (max 25 LPM)
13-15 kg	30 LPM
16-30 kg	35 LPM
31-50 kg	40 LPM
> 50 kg	50 LPM

CPAP: Continuous Positive Airway Pressure

- Delivers gas flow at changing flow rates to provide same positive airway pressure throughout the entire respiratory cycle
  - Prevents alveolar collapse – increase FRC, prevents atelectasis
  - Decreased inspiratory muscle activity – decrease WOB
  - Improves oxygenation

Does the mode of support change outcome?

Can it prevent PICU admission? Can it prevent intubation? Shorten LOS?

Original article

High-flow nasal cannula therapy for children with bronchiolitis: a systematic review and meta-analysis

Jilei Lin,[1,2] Yin Zhang,[1,2] Limei Xiong,[1,2] Sha Liu,[1] Caihui Gong,[1] Jihong Dai[1,2]

Arch Dis Child 2019;**104**:564–576.

Outcome	HFNP vs. LFNP	HFNP vs nCPAP
Treatment Failure	Reduced with HFNP (RR 0.5, 95%CI 0.4-0.62, p<0.01) ** LFNP: 75% did not fail; 61% of patients who failed rescued by HFNP **	Reduced with nCPAP (RR 0.61, 95%CI 1.06-2.42, p=0.02) * 72% HFNP failure rescued by CPAP * * 82% nCPAP failure rescued by HFNP *
LOS	No reduction with HFNP (MD -1.53, 95%CI -3.33 to 0.27, p=0.1)	No difference (MD 0.5, 95%CI-0.66 to 1.66, p=0.4)
Need for PICU	No reduction with HFNP (RR 1.3, 95%CI 0.98-1.72, p=0,06)	N/A
Need for intubation	No reduction with HFNP (RR 1.98, 95%CI 0.60-6.56, p=0.26)	No difference (RR 0.96, 95%CI 0.35-2.61, p=0.93)

Original article

High-flow nasal cannula therapy for children with bronchiolitis: a systematic review and meta-analysis

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Arch Dis Child 2019;104:564–576.

Applying HFNC early in the course of bronchiolitis

□□ expect **~70% of that use will be unnecessary**

Outcome	HFNP vs. LFNP	HFNP vs nCPAP
Treatment Failure		
LOS		p=0.4)
Need	p=0,06)	N/A
Need for intubation	No reduction with HFNP (RR 1.98, 95%CI 0.60-6.56, p=0.26)	No difference (RR 0.96, 95%CI 0.35-2.61, p=0.93)

LFNP *or* HFNP *or* CPAP*???*

For the Hypoxemic Patient with Bronchiolitis,

Don't Underestimate LFNP!

Start with LFNP → **HFNP as 'rescue' therapy if LFNP fails** → **Consider CPAP if poor response to HFNP***

Re-evaluate *often* *if no improvement after 90min, escalate care*

Case 1b

- LFNP 1LPM: VS: HR 160, RR 55, SpO2 94%
- 2h later, on LFNP 1 LPM:
  - HR 180, RR65, SpO2 91%, severe WOB
  - Cap gas: 7.29 / 62 / 23, lactate 1.8

BIPAP: Bilevel Positive Airway Pressure

- Delivers 2 different levels of positive airway pressure depending on the phase of the respiratory cycle
  - *Inspiratory* Positive Airway Pressure (IPAP)
    - Ventilator delivers a higher pressure during inspiratory phase
    - Supports the patient's inspiratory effort
  - *Expiratory* Positive Airway Pressure (EPAP)
    - Ventilator delivers a lower pressure when inspiration phase terminates
    - Prevent airway/alveolar collapse
    - Increases FRC

BIPAP Initiation

- **Interface:** Nasal; Full face (mouth and nose); Total face mask (Performax)




BIPAP Initiation

- Mode: Spontaneous vs. Controlled/Timed
- Set EPAP/IPAP:
  - EPAP = Start 5-6 cm H2O
    - reflective of intrinsic PEEP; used to optimize resting lung volume   improves oxygenation
  - IPAP = Start 12 cmH2O
    - reflective of Peak pressure; adjust to achieve adequate chest rise/tidal improves ventilation

IPAP/EPAP: 12/6   14/7   16/8   20/10

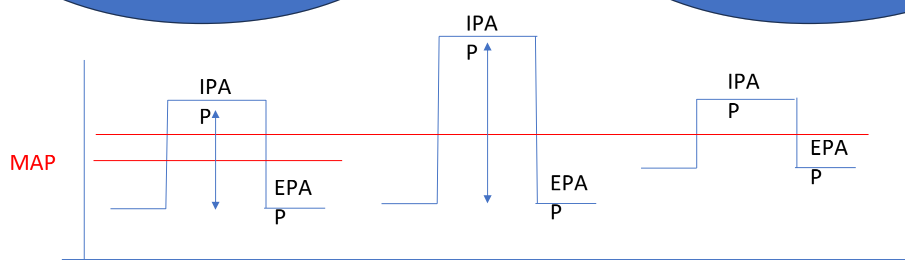
Difference between IPAP and EPAP contributes to tidal volume

IPAP ≥ 20 cmH2O: consider alternative therapy (intubation)

BIPAP Management

Not enough chest rise/low Vt:
Progressively increase IPAP (no change to EPAP) to increase the driving pressure (IPAP – EPAP)

Inadequate oxygenation/ atelectasis on CXR:
Increase EPAP – optimizes resting lung volume and increase mean airway pressure



BIPAP Management

- Don't forget:
  - Optimize airway positioning
  - Suctioning!!
  - OG/NG tube placement

- Reassess frequently!
  - Chest rise, WOB, RR, HR, SpO2
  - Triggering breath
  - Delivered tidal volume (Vt)
  - Gases: PaCO2 clearance +/- PaO2

  - Increased risk of intubation (Clayton *et al. Pediatr Crit Care Med* 2019)

Case 1b

- BiPAP started and titrated to 12/6, FiO2 60%
- WOB decreased
- Infant becoming more irritable and 'fighting against the BiPAP'

NIV Management: Sedation

- Non-pharmacologic strategies: Bundling? Decrease handling? Feeds?
- Pharmacologic options:
  - Episodic agitation   intermittent:
    - Chloral hydrate (5-15 mg/kg q4H PO/PR)
    - Clonidine (1-2mcg/kg q4-6h PO)
    - Midazolam (0.3-0.5 mg/kg IN; 0.025-0.05 mg/kg IV)
    - Ketamine (0.5-1mg/kg IV)
  - Recurrent agitation   infusion:
    - Midazolam (30-200 mcg/kg/h)
    - Morphine (10-40 mcg/kg/h)
    - Ketamine (5-20 mcg/kg/min) – bronchorrhea
    - Dexmedetomidine (0.1-1 mcg/kg/h)

Clonidine PO / Dexmedetomidine IV-IN:
- Alpha-agonists
- Sedative, Anxiolysis, Analgesic
- Minimal resp depression
- SE: bradycardia, hypotension

Case 2

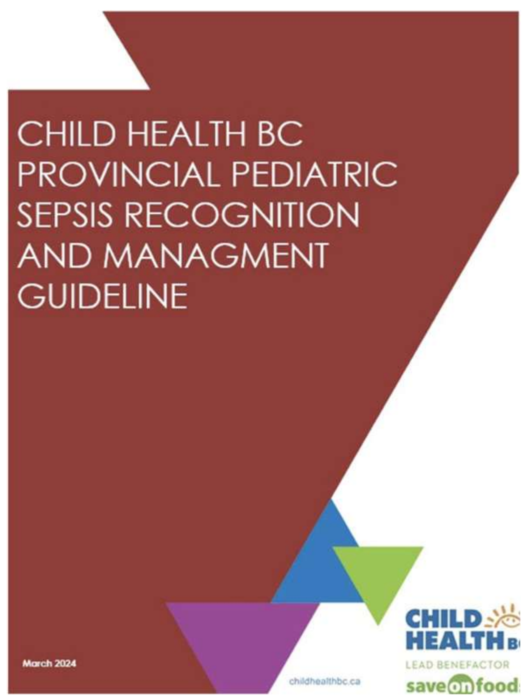
- 11yo, 30kg, previously healthy, presents with 2days of fever. Difficult to rouse this morning has been confused all day.
  - HR 150, BP 70/35, RR 20, SpO2 94%, Temp 40C
  - Lethargic
  - Cold peripheries.
  - CRT 5-6 sec.
  - Diffuse maculopapular rash

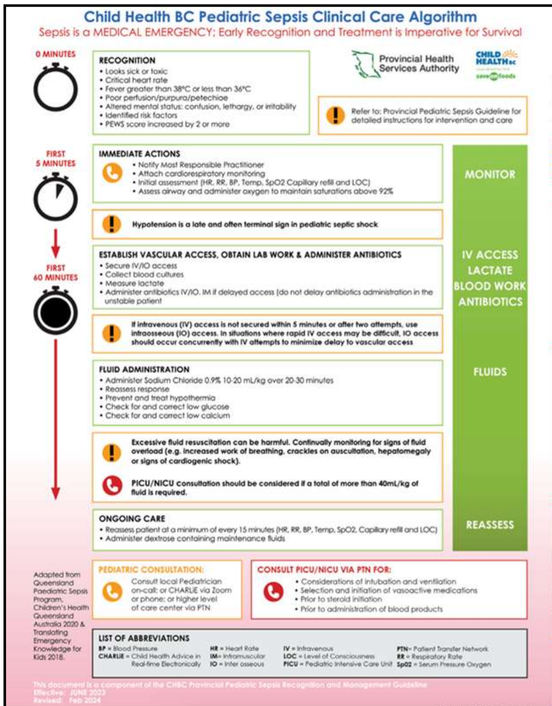
Sepsis?

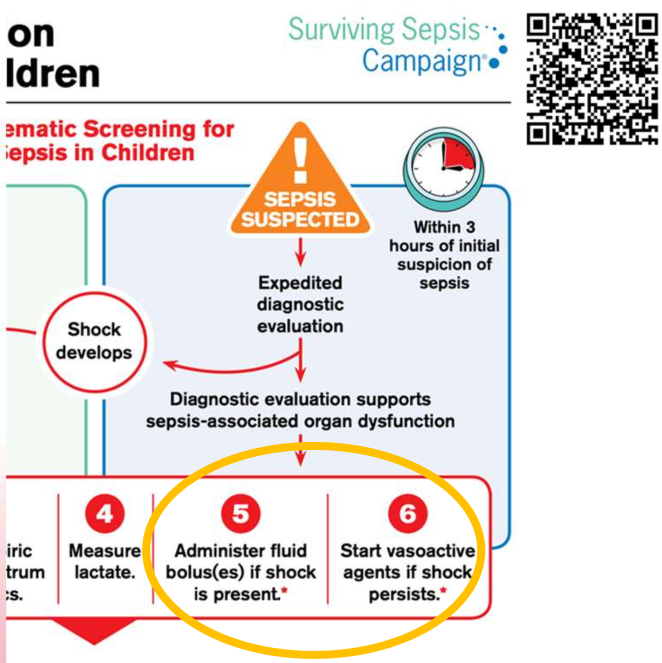
Sepsis: Life threatening organ dysfunction caused by a dysregulated host response to infection

Septic Shock: Severe infection leading to cardiovascular dysfunction (including hypotension, need for treatment with vasoactive medications, or impaired perfusion)

Early Recognition and Treatment Saves Lives!







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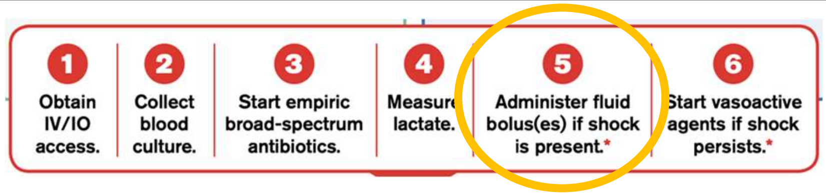
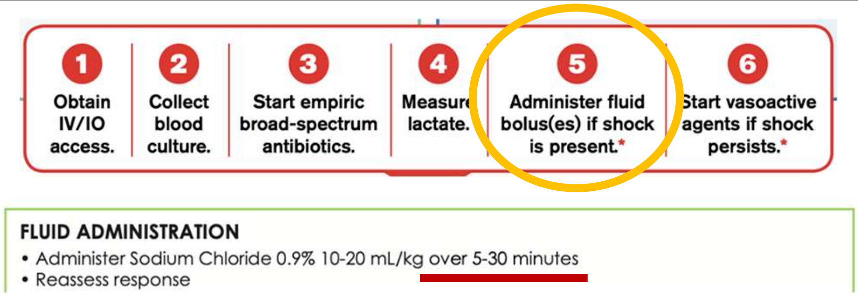
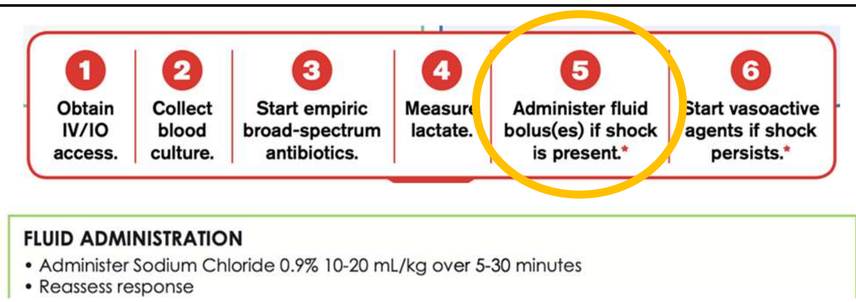



FLUID ADMINISTRATION
- Administer Sodium Chloride 0.9% 10-20 mL/kg over 5-30 minutes
- Reassess response

- ***Type of Fluid:***
  - Use crystalloids (0.9% NaCl)
  - Balanced/buffered crystalloids are also OK! (Plasma-Lyte; Lactated Ringer’s)
    - Weak recommendation from Surviving Sepsis Guideline
      - Adults RCTs: improved inflammation / AKI / mortality + reduced hyperchloremic acidosis
      - Peds: observational studies showed lower mortality; RCT showed decreased AKI



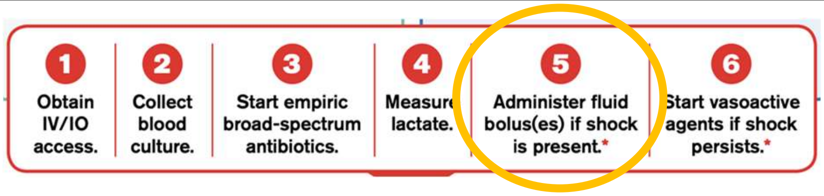
- ***How fast?***
  - Faster is okay too… (Sankar et al. *Pediatr Crit Care Med* 2017)
    - Fast (5-10 min) vs. Slow (15-20 min)
      - Fast shown to increase risk of intubation (role of fluid overload?)
      - No difference in mortality, LOS, resolution of shock



PICU/NICU consultation should occur if a **total of > 40mL/kg** of fluid

(max 60 ml/kg within the first hour)

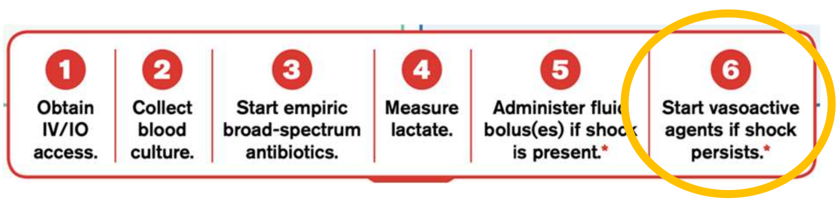
- ***How much fluid?***
  - If ICU NOT locally available: (FEAST trial, Maitland et al. NEJM 2011)
    - Liberal fluid resuscitation strategy led to increase mortality
    - No hypotension – start maintenance fluid
    - Hypotension – up to 40 mL/kg in bolus fluid (10–20 mL/kg per bolus) over the first hour
  - If ICU locally available: up to 40–60 mL/kg in bolus fluid (10–20 mL/kg per bolus) over the first hour
    - Restrictive vs. Liberal fluid resuscitation strategies showed no difference in mortality



FLUID ADMINISTRATION
- Administer Sodium Chloride 0.9% 10-20 mL/kg over 5-30 minutes
- Reassess response

Excessive fluid resuscitation can be harmful!

- Reassess often (*q15min*)
- Titrate to clinical response: improved cardiac output (improved mentation, HR, CRT, UO)
- Monitor for signs of fluid overload: increased work of breathing, crackles on auscultation, hepatomegaly



- Consider vasoactive medications in the presence of fluid-refractory shock
  - persistent signs of shock after 60ml/kg fluid resuscitation OR
  - lack of clinical response to fluid bolus OR signs of fluid overload
- Epinephrine OR Norepinephrine > Dopamine
  - Choice dependent on physiology; clinician preference; and local system factors
    - E.g., NE: low vascular resistance vs. Epi: myocardial dysfunction
  - Can be given peripheral IV or IO
  - Starting dose 0.05 mcg/kg/min

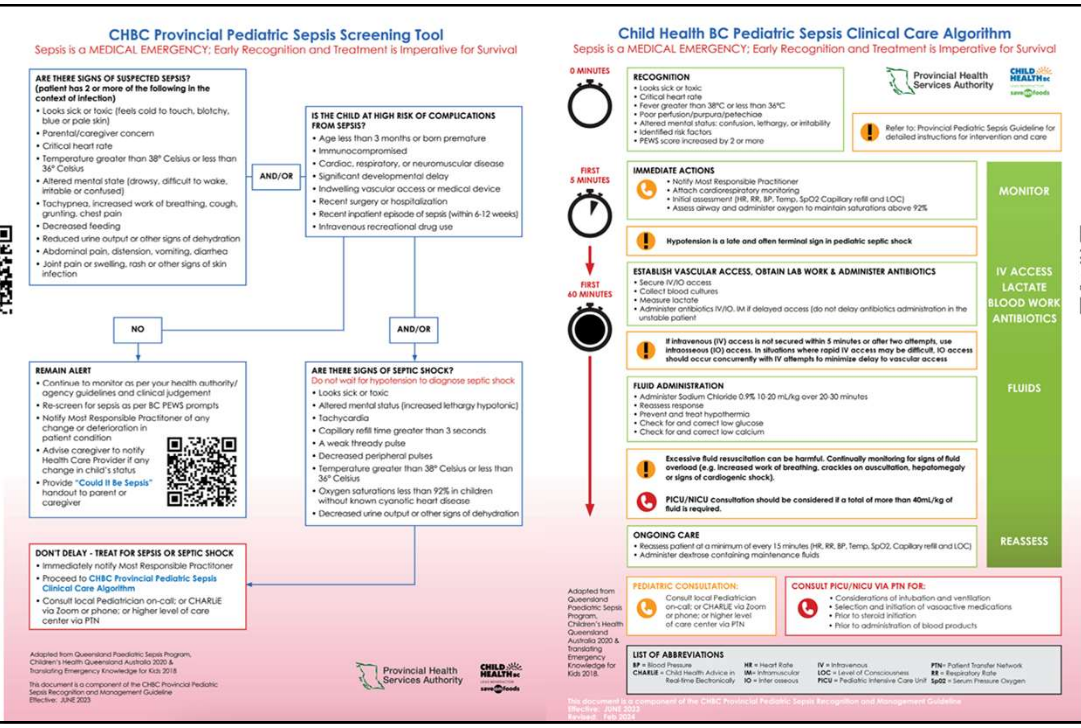
ONGOING CARE

- Reassess patient at a minimum of every 15 minutes (HR, RR, BP, Temp, SpO2, Capillary Refill and LOC)
- Administer dextrose containing maintenance fluids

REASSESS REASSESS REASSESS

End-Points of Resuscitation:

- Heart Rate – within age-appropriate range
- Blood Pressure – 5-50th %tile for age
- Capillary Refill Time – 2-3 sec
- Urine Output – > 1ml/kg/hr
- Improved Mental Status
- Lactate – < 2



CHBC Provincial Pediatric Sepsis Screening Tool

Sepsis is a MEDICAL EMERGENCY; Early Recognition and Treatment is Imperative for Survival

ARE THERE SIGNS OF SUSPECTED SEPSIS? (patient has 2 or more of the following in the context of infection)
- Looks sick or toxic (feels cold to touch, blotchy, blue or pale skin)
- Parental/caregiver concern
- Critical heart rate
- Temperature greater than 38° Celsius or less than 36° Celsius
- Altered mental state (drowsy, difficult to wake, irritable or confused)
- Tachypnea, increased work of breathing, cough, grunting, chest pain
- Decreased feeding
- Reduced urine output or other signs of dehydration
- Abdominal pain, distension, vomiting, diarrhea
- Joint pain or swelling, rash or other signs of skin infection

AND/OR

IS THE CHILD AT HIGH RISK OF COMPLICATIONS FROM SEPSIS?
- Age less than 3 months or born premature
- Immunocompromised
- Cardiac, respiratory, or neuromuscular disease
- Significant developmental delay
- Indwelling vascular access or medical device
- Recent surgery or hospitalization
- Recent inpatient episode of sepsis (within 6-12 weeks)
- Intravenous recreational drug use

NO

AND/OR

REMAIN ALERT
- Continue to monitor as per your health authority/agency guidelines and clinical judgement
- Re-screen for sepsis as per BC PEWS prompts
- Notify Most Responsible Practitoner of any change or deterioration in patient condition
- Advise caregiver to notify Health Care Provider if any change in child's status
- Provide "Could It Be Sepsis" handout to parent or caregiver

ARE THERE SIGNS OF SEPTIC SHOCK?
Do not wait for hypotension to diagnose septic shock
- Looks sick or toxic
- Altered mental status (increased lethargy hypotonic)
- Tachycardia
- Capillary refill time greater than 3 seconds
- A weak thready pulse
- Decreased peripheral pulses
- Temperature greater than 38° Celsius or less than 36° Celsius
- Oxygen saturations less than 92% in children without known cyanotic heart disease
- Decreased urine output or other signs of dehydration

DON'T DELAY - TREAT FOR SEPSIS OR SEPTIC SHOCK
- Immediately notify Most Responsible Practitoner
- Proceed to CHBC Provincial Pediatric Sepsis Clinical Care Algorithm
- Consult local Pediatrician on-call; or CHARLiE via Zoom or phone; or higher level of care center via PTN

Adapted from Queensland Paediatric Sepsis Program, Children's Health Queensland Australia 2020 & Translating Emergency Knowledge for Kids 2018

This document is a component of the CHBC Provincial Pediatric Sepsis Recognition and Management Guideline
Effective: JUNE 2023

Provincial Health Services Authority

Child Health BC Pediatric Sepsis Clinical Care Algorithm

Sepsis is a MEDICAL EMERGENCY; Early Recognition and Treatment is Imperative for Survival

0 MINUTES

RECOGNITION
- Looks sick or toxic
- Critical heart rate
- Fever greater than 38°C or less than 36°C
- Poor perfusion/purpura/petechiae
- Altered mental status: confusion, lethargy, or irritability
- Identified risk factors
- PEWS score increased by 2 or more

Refer to: Provincial Pediatric Sepsis Guideline for detailed instructions for intervention and care

FIRST 5 MINUTES

IMMEDIATE ACTIONS
- Notify Most Responsible Practitioner
- Attach cardiorespiratory monitoring
- Initial assessment (HR, RR, BP, Temp, SpO2 Capillary refill and LOC)
- Assess airway and administer oxygen to maintain saturations above 92%

MONITOR

Hypotension is a late and often terminal sign in pediatric septic shock

FIRST 60 MINUTES

ESTABLISH VASCULAR ACCESS, OBTAIN LAB WORK & ADMINISTER ANTIBIOTICS
- Secure IV/IO access
- Collect blood cultures
- Measure lactate
- Administer antibiotics IV/IO. IM if delayed access (do not delay antibiotics administration in the unstable patient

IV ACCESS
LACTATE
BLOOD WORK
ANTIBIOTICS

If intravenous (IV) access is not secured within 5 minutes or after two attempts, use intraosseous (IO) access. In situations where rapid IV access may be difficult, IO access should occur concurrently with IV attempts to minimize delay to vascular access

FLUID ADMINISTRATION
- Administer Sodium Chloride 0.9% 10-20 mL/kg over 20-30 minutes
- Reassess response
- Prevent and treat hypothermia
- Check for and correct low glucose
- Check for and correct low calcium

FLUIDS

Excessive fluid resuscitation can be harmful. Continually monitoring for signs of fluid overload (e.g. increased work of breathing, crackles on auscultation, hepatomegaly or signs of cardiogenic shock).

PICU/NICU consultation should be considered if a total of more than 40mL/kg of fluid is required.

ONGOING CARE
- Reassess patient at a minimum of every 15 minutes (HR, RR, BP, Temp, SpO2, Capillary refill and LOC)
- Administer dextrose containing maintenance fluids

REASSESS

Adapted from Queensland Paediatric Sepsis Program, Children's Health Queensland Australia 2020 & Translating Emergency Knowledge for Kids 2018.

PEDIATRIC CONSULTATION:
Consult local Pediatrician on-call; or CHARLiE via Zoom or phone; or higher level of care center via PTN

CONSULT PICU/NICU VIA PTN FOR:
- Considerations of intubation and ventilation
- Selection and initiation of vasoactive medications
- Prior to steroid initiation
- Prior to administration of blood products

LIST OF ABBREVIATIONS

BP = Blood Pressure
CHARLiE = Child Health Advice in Real-time Electronically
HR = Heart Rate
IM = Intramuscular
IO = Inter osseous
IV = Intravenous
LOC = Level of Consciousness
PICU = Pediatric Intensive Care Unit
PTN = Patient Transfer Network
RR = Respiratory Rate
Sp02 = Serum Pressure Oxygen

This document is a component of the CHBC Provincial Pediatric Sepsis Recognition and Management Guideline
Effective: JUNE 2023
Revised: Feb 2024

Summary

Bronchiolitis

- Hypoxemic patient with bronchiolitis: *don't underestimate LFNP*
  - No benefit to using HFNP as first-line, reserve as 'rescue' therapy
- Moderate/Severe bronchiolitis:
  - Consider HFNC first-line (equivocal to nCPAP): 'dose' ≈ 2 L/kg/min (up to 25 LPM)
  - Consider BiPAP: starting 'dose' = 12 / 6 + alpha-agonist PRN

Sepsis

- Early recognition of sepsis/septic shock saves lives!
- Excessive fluid resuscitation can be harmful! – monitor fluid resuscitation closely
- If vasoactives needed: Epi *OR* Norepi

- Child Health BC Provincial Pediatric Sepsis Recognition and Management Guideline (March 2024). https://shop.healthcarebc.ca/phsa/BCWH_2/CW%20Campus%20Wide/C-0506-07-62987.pdf (Accessed Sept 19, 2024).
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