Clinical Pearls for the Crashing Pediatric Patient

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Objectives:
1. Define clinical manifestations of early shock in the pediatric patient.
2. Recognize new trends in pediatric resuscitation.
3. Discuss the new changes made to the pediatric resuscitation guidelines.

Definition
Shock develops when systemic oxygen and nutrient supply become inadequate to meet the metabolic demands of the body’s organ systems.
- Compensated shock
- Decompensated shock
- Irreversible shock

Pediatric Shock
1) Distributive
   e. Septic
      i. Antibiotics, IVF
   f. Anaphylactic
      i. “Home-remedies”
      ii. Formula
   g. Neurogenic
      i. Seizure
   ii. (Non-accidental) Trauma
2) Cardiogenic
   e. Heart lesion
      i. Obstructive
      ii. Cyanotic
         1. Hyperoxia test
      iii. Prostaglandin
   f. Anomalous coronary artery
      i. EKG
   g. Supraventricular tachycardia (SVT)
3) **Hypovolemic**
   e. Blood loss
      i. 10 ml/kg PRBC
   f. Fluid loss
      i. 10-20 ml/kg normal saline bolus

4) **Obstructive**
   e. Malrotation with volvulus
   f. Diaphragmatic hernia
   g. Necrotizing enterocolitis

5) **Endocrine/ metabolic**
   e. Congenital adrenal hyperplasia (CAH)
      i. Low sodium, high potassium
      ii. Hydrocortisone
   f. **Glucose**!!!
      i. Rule of 50
   g. **Inborn error or metabolism**
      i. Glucose
      ii. Lactate
      iii. Ammonia
      iv. Ketonuria

- **T** – trauma, non-accidental trauma
- **H** – heart disease, hypovolemia, hypoxia
- **E** – endocrine (CAH, thyrotoxicosis)
- **M** – metabolic
- **I** – inborn errors of metabolism
- **S** – sepsis
- **F** – formula (dilution or concentration)
- **I** – intestinal catastrophies
- **T** – toxins
- **S** - seizures
Pediatric shock: early recognition and management

a. Airway
   i. Cuffed tubes okay!
   ii. ETT size: \((\text{Age}/4) + 4\), decrease by \(\frac{1}{2}\) size if using cuffed

**Anatomy**

<table>
<thead>
<tr>
<th></th>
<th>Infant</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tongue</td>
<td>Relatively large, intraoral</td>
<td>Normal</td>
</tr>
<tr>
<td>Epiglottis</td>
<td>Floppy, anterior, cephalad</td>
<td>Firm</td>
</tr>
<tr>
<td>Vocal cord angle</td>
<td>Inclined</td>
<td>Flat</td>
</tr>
<tr>
<td>Glottis</td>
<td>C3 level</td>
<td>C5-C6 level</td>
</tr>
<tr>
<td>Cricothyroid Membrane</td>
<td>Small, narrowest point</td>
<td>Normal</td>
</tr>
<tr>
<td>Trachea</td>
<td>Small, short, collapsible</td>
<td>Large, stationary</td>
</tr>
</tbody>
</table>

b. Breathing
   i. Measure RR over 30 seconds
   ii. Increase temp by 1°C = increase RR by 2-5

**Age adjusted rates**

<table>
<thead>
<tr>
<th>Age</th>
<th>RR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>30-60</td>
</tr>
<tr>
<td>Toddler</td>
<td>24-40</td>
</tr>
<tr>
<td>Preschooler</td>
<td>22-34</td>
</tr>
<tr>
<td>School-aged</td>
<td>18-30</td>
</tr>
<tr>
<td>Adolescent</td>
<td>12-16</td>
</tr>
</tbody>
</table>

- **< 60**
- **< 30**
- **< 15**

C. Circulation
   v. \((\text{Age} \times 2) + 90\) = median 50% percentile for SBP
   vi. Early use of intraosseous access
   vii. NS bolus (20 ml/kg) EXCEPT neonates or congenital cardiac (10 ml/kg)
   viii. PRBC/ FFP 10 ml/kg (5 ml/kg in neonates)

d. Dextrose!!! All ill-appearing infants are hypoglycemic until proved otherwise!
   i. Rule of 50-100
      1. \(D_{10}\) 5-10 ml/kg (age < 1 year)
      2. \(D_{25}\) 2-4 ml/kg (age 1 – 8 year)
      3. \(D_{50}\) 1-2 ml/kg (age > 8 year)
e. Vital signs
   i. Always measure in kilograms!!!

Newborns

- Recognize decreased perfusion, cyanosis, and RDS. Maintain airway and establish access according to NRP guidelines.

**Initial resuscitation:** Push boluses of 10 cc/kg isotonic saline or colloid up to 60 cc/kg until perfusion improves, unless hepatomegaly develops. Correct hypoglycemia & hypocalcemia. Begin antibiotics. Begin prostaglandin until ductal-dependent lesion is ruled out.

**Fluid refractory shock:** Titrate dopamine 5-9 mcg/kg/min. Add dobutamine up to 10 mcg/kg/min.

**Fluid refractory dopamine-resistant shock:** Titrate epinephrine 0.05 to 0.3 mcg/kg/min.

**Catecholamine resistant shock:** Monitor CVP in NICU, attain normal MAP-CVP & ScvO₂ > 70%.

- SVC flow > 40 mL/Kg/min or CI > 3.3 L/m²/min

**Cold shock with normal blood pressure & evidence of poor LV function**
- If ScvO₂ < 70%
- SVC flow < 40 mL/Kg/min or CI < 3.3 L/m²/min
- Add vasodilator (nitrovasodilators, milrinone) with volume loading.

**Cold shock with low blood pressure & evidence of RV dysfunction**
- If PPHN with ScvO₂ < 70%
- SVC flow < 40 mL/Kg/min or CI < 3.3 L/m²/min
- Add inhaled nitric oxide, consider milrinone, consider inhaled iloprost or IV adenosine.

**Warm shock with low blood pressure:**
- Add volume & norepinephrine. Consider vasopressin, terlipressin, or angiotensin. Use inotropes to keep ScvO₂ > 70%.
- SVC flow > 40 mL/Kg/min & CI > 3.3 L/m²/min

**Refractory shock:** Rule out & correct pericardial effusion, pneumothorax.
- Use hydrocortisone for absolute adrenal insufficiency, and T₃ for hypothyroidism.
- Begin pentoxifylline if VLBW newborn. Consider closing PDA if hemodynamically significant.

**shock not reversed?**

ECMO

**Infants and Children**

- **Initial resuscitation:** Push boluses of 20 cc/kg isotonic saline or colloid up to & over 60 cc/kg until perfusion improves or unless rales or hepatomegaly develop. Correct hypoglycemia & hypocalcemia. Begin antibiotics.
- **Fluid refractory shock:** Begin inotrope IV/IO. use atropine/ketamine IV/IO/IM to obtain central access & airway if needed. 
  - Reverse cold shock by titrating central dopamine
  - or, if resistant, titrate central epinephrine
  - Reverse warm shock by titrating central norepinephrine.
- **Catecholamine resistant shock:** Begin hydrocortisone if at risk for absolute adrenal insufficiency
- **Cold shock with normal blood pressure:**
  1. Titrate fluid & epinephrine, ScvO₂ > 70%, Hgb > 10g/dL
  2. If ScvO₂ still < 70%
     - Add vasodilator with volume loading (nitrovasodilators, milrinone, imrinone, & others)
     - Consider levosimendan
- **Cold shock with low blood pressure:**
  1. Titrate fluid & epinephrine, ScvO₂ > 70%, Hgb > 10 g/dL
  2. If still hypotensive consider norepinephrine
  3. If ScvO₂ still < 70% consider dobutamine, milrinone, enoximone or levosimendan
- **Warm shock with low blood pressure:**
  1. Titrate fluid & norepinephrine, ScvO₂ > 70%.
  2. If still hypotensive consider vasopressin, terlipressin or angiotensin
  3. If ScvO₂ still < 70% consider low dose epinephrine

**Persistent catecholamine resistant shock:** Rule out and correct pericardial effusion, pneumothorax, & intra-abdominal pressure >12 mm/Hg.

Consider pulmonary artery, PICCO, or FATD catheter, &/or doppler ultrasound to guide fluid, inotrope, vasopressor, vasodilator and hormonal therapies.

Goal C.I. > 3.3 & < 6.0 L/min/m²

**Refractory shock:** ECMO
### SIRS: Age-specific vital signs and laboratory values

<table>
<thead>
<tr>
<th>Age group</th>
<th>Tachycardia</th>
<th>Bradycardia</th>
<th>Respiratory rate</th>
<th>WBC x 10³/mm³</th>
<th>Systolic BP mmHg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>&gt;180</td>
<td>&lt;100</td>
<td>&gt;50</td>
<td>&gt;34</td>
<td>&lt;65</td>
</tr>
<tr>
<td>Neonate</td>
<td>&gt;180</td>
<td>&lt;100</td>
<td>&gt;40</td>
<td>&gt;19.5 or &lt;5</td>
<td>&lt;75</td>
</tr>
<tr>
<td>Infant</td>
<td>&gt;180</td>
<td>&lt;90</td>
<td>&gt;34</td>
<td>&gt;17.5 or &lt;5</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Toddler</td>
<td>&gt;140</td>
<td>-</td>
<td>&gt;22</td>
<td>&gt;15.5 or &lt;6</td>
<td>&lt;94</td>
</tr>
<tr>
<td>Child</td>
<td>&gt;130</td>
<td>-</td>
<td>&gt;18</td>
<td>&gt;13.5 or &lt;4.5</td>
<td>&lt;105</td>
</tr>
<tr>
<td>Adolescent</td>
<td>&gt;110</td>
<td>-</td>
<td>&gt;14</td>
<td>&gt;11 or &lt;4.5</td>
<td>&lt;117</td>
</tr>
</tbody>
</table>


### Therapies adults and children with septic shock

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>Usually need more fluid, up to and over 60 ml/kg</td>
<td>Fluid resuscitation to CVP 12</td>
</tr>
<tr>
<td>Antibiotics</td>
<td>Early initiation of appropriate antibiotics within 1 hour</td>
<td>Early initiation of appropriate antibiotics within 1 hour</td>
</tr>
<tr>
<td>Inotropes and vasopressors</td>
<td>First line peripheral epinephrine cold shock, transition to central when able. Central norepinephrine for warm shock</td>
<td>First line norepinephrine ± dobutamine</td>
</tr>
<tr>
<td>Vasodilators</td>
<td>Use for pulmonary hypertension, Low CO, high SVR shock</td>
<td>No role</td>
</tr>
<tr>
<td>Tight glycemic control</td>
<td>Unresolved</td>
<td>Harmful</td>
</tr>
<tr>
<td>ECMO</td>
<td>Survival 80% neonates, 50% children</td>
<td>Evolving H1N1 popularizing use</td>
</tr>
<tr>
<td>Inhaled NO</td>
<td>Neonates with RV failure</td>
<td>No role</td>
</tr>
<tr>
<td>Hydrocortisone</td>
<td>Absolute adrenal insufficiency only; post ACTH cortisol level &lt;18 μg/dL or baseline &lt;5 μg/dL</td>
<td>Use if continue on vasopressors regardless of adrenal status</td>
</tr>
</tbody>
</table>

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**Pediatric Basic Life Support**

- Change in sequence C-A-B
- Eliminated “look, listen and feel” to assess breathing after opening airway
- Lay rescuers: check for response of abnormal breathing (eliminate pulse check)
  - Health care providers: allows 10 sec for pulse check
    - 30 compressions followed by 2 breaths (lone rescuer)
    - 15:2 if two providers
- “Push hard, push fast” at least 100 per minute, allowing recoil of chest
  - Infant chest compression 1.5 in (4 cm)
  - Children – 2 in (5 cm)
- Defibrillation
  - Manual defibrillator > AED with dose attenuator > AED without dose attenuator
  - 2-4 J/kg, followed by at least 4 J/kg, up to 10 J/kg

**Pediatric Advanced Life Support**

- BVM recommended over ETI for out-of-hospital setting
  - Experienced providers may use LMAs
- Cricoid pressure NOT recommended
- Cuffed tubes okay!
  - Uncuffed: \((\text{age}/4) + 4 = \text{mm ID}\)
  - Cuffed: \((\text{age}/4) + 3.5 = \text{mm ID}\)
- Capnography recommended to confirm ETT placement and assess adequacy of CPR
- Avoid excessive ventilation (8-10 breaths per minute)
- Oxygen – increasing evidence for harm, especially in neonates
  - Avoid hyperoxemia
  - Start with 100% O₂ then titrate to maintain \(\text{SpO}_2 > 94\%\)
- Medications
  - Addition of procainamide as possible therapy for refractory SVT
  - Routine calcium administration NOT recommended unless clear indication
  - Etomidate may be used for RSI but NOT recommended in septic shock
  - Atropine may be added for symptomatic bradycardia but not cardio-pulmonary arrest
- Wide-complex tachycardia present of QRS width >0.09 sec
- Post-arrest Care
  - Therapeutic hypothermia may be considered in children with ROSC (large trial underway)
- Family presence during resuscitation is recommended
- New topics:
  - Specific guidance for cardiac arrest in infants with single-ventricle anatomy, Fontan or hemi-Fontan/ bidirectional Glenn physiology and pulmonary hypertension
  - Autopsies recommended for young victims of sudden cardiac arrest
Neonatal resuscitation

- Maintain A-B-C sequence
- De-emphasis on peripartum suctioning
- ET suctioning for nonvigorouos neonate in meconium-stained fluid.
- Vigorous newborns do not require ET suctioning of meconium regardless of how thick the meconium is.
- Determine degree of oxygenation by pulse ox on the right wrist or arm
- Term babies should be resuscitated with room air first, then supplemental oxygen if needed by blended oxygen-air delivery
  - If bradycardic after 90 sec of resuscitation, increased oxygen to 100%
- Start CPR for HR < 60 bpm despite assisted ventilation for 30 seconds.
- Preferred method is thumb-hand technique.
- Compression:ventilation ratio 3:1 (90 compressions with 30 ventilations per cycle)
- Infants >36 weeks with moderate to severe hypoxic-ischemic encephalopathy should be offered therapeutic hypothermia

<table>
<thead>
<tr>
<th></th>
<th>Adults/ Adolescents</th>
<th>Infants/ Children</th>
<th>Neonates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sequence</strong></td>
<td>C-A-B</td>
<td>C-A-B</td>
<td>A-B-C</td>
</tr>
<tr>
<td><strong>Compression rate (bpm)</strong></td>
<td>100</td>
<td>100</td>
<td>90:30 events/min</td>
</tr>
<tr>
<td><strong>Depth</strong></td>
<td>&gt;2 inches</td>
<td>1.5-2 inches</td>
<td>1/3 AP diameter</td>
</tr>
<tr>
<td><strong>Compression:ventilation ratio</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1 rescuer</td>
<td>30:2</td>
<td>30:2</td>
<td>3:1</td>
</tr>
<tr>
<td>- 2 rescuers</td>
<td>30:2</td>
<td>15:2</td>
<td>3:1</td>
</tr>
<tr>
<td><strong>Pause for ventilation after intubation?</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Key references: