Critical Care in Infants and Children: The Basics

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Objectives

- Review pediatric physiology and pathology
- Understand differences in adult and pediatric critical care
- Describe modifications to adult therapies needed to support children
Important Aspects of Physical Examination

- General appearance
  - Responsiveness and reactivity
  - Level of activity, muscle tone
  - Irritability, consolability, cry

- Skin perfusion
  - Color of mucosa and nail beds
  - Capillary refill <2 sec

- Degree of hydration
  - Fontanelle, presence/absence of tears, sunken eyes, skin tenting, moistness of mucous membranes

- Respiratory rate and respiratory effort
  - Tachypnea
  - Grunting, nasal flaring, retractions (subcostal, tracheal, intercostal)

- Bradypnea
# General Examination: Vital Signs

In neonates, MAP can be estimated by gestational age:

MAP can be estimated by $55 + (\text{age} \times 1.5)$

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Heart Beat (beats/min)</th>
<th>Respiratory Rate (breaths/min)</th>
<th>Blood Pressure (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preemie</td>
<td>120-170</td>
<td>40-70</td>
<td>55-75/35-45</td>
</tr>
<tr>
<td>Newborn</td>
<td>110-160</td>
<td>30-60</td>
<td>65-85/45-55</td>
</tr>
<tr>
<td>Infant</td>
<td>90-150</td>
<td>25-45</td>
<td>70-100/50-65</td>
</tr>
<tr>
<td>1-3 years</td>
<td>80-125</td>
<td>20-30</td>
<td>90-105/55-70</td>
</tr>
<tr>
<td>3-6 years</td>
<td>70-115</td>
<td>20-25</td>
<td>95-110/60-75</td>
</tr>
<tr>
<td>6-12 years</td>
<td>60-100</td>
<td>14-22</td>
<td>100-120/60-75</td>
</tr>
<tr>
<td>&gt;12 years</td>
<td>60-100</td>
<td>12-18</td>
<td>100-120/70-80</td>
</tr>
</tbody>
</table>
Case Study 1

- 6-month-old former 30 weeks gestational age infant with fever, rhinitis, and cough for 4 days
- T 38.5°C, HR 150 beats/min, RR 60 breaths/min, Sao₂ 90%
- Tachypneic with subcostal and upper sternal retractions and copious upper airway secretions
- Minimal improvement with 100% O₂ and nebulized albuterol

What is the most important initial intervention?

What are the most immediate treatment strategies?
Evaluation by Organ System: Respiratory System/Airway

- Increased chest wall compliance secondary to cartilaginous thoracic cavity

What are some early signs of respiratory distress in an infant/child?

- Hypoxemia occurs quickly in infants/children
  - Infant oxygen consumption is 2-3 times greater than adult
  - Children have lower hemoglobin levels than adults

What is the most important step in treating a child with respiratory compromise?

What are simple early interventions in management of a child with respiratory compromise?
What are some anatomic differences between the pediatric and adult airways?

- Pediatric airway as compared to adult airway
- Tongue is larger in proportion to mouth
- Pharynx is smaller
- Epiglottis is larger and floppier
- Larynx is more anterior and superior
- Narrowest at cricoid
- Trachea narrow and less rigid
General considerations for intubation

- Nasogastric tube may be needed
- Obstruction can occur easily
- Positioning in “sniffing” position with assistance of shoulder roll is important
- Use of straight laryngoscope blade, cricoid pressure, or lateral displacement may help with visualization

Uncuffed ETT size = (age/4) + 4

Estimate of ETT depth = inner diameter of ETT x 3
**Causes of Respiratory Failure**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cause</th>
</tr>
</thead>
</table>
| Premature neonates       | Apnea of prematurity  
                          | Infant respiratory distress syndrome (surfactant deficiency and ineffective chest bellows) |
| Term neonates            | Bacterial pneumonia  
                          | Meconium aspiration  
                          | Congenital airway abnormalities |
| Infants, toddlers        | Pneumonia  
                          | Bronchiolitis  
                          | Asthma  
                          | Foreign-body aspiration  
                          | Upper airway obstruction due to infection |

Primary respiratory disorders are the most common cause for cardiopulmonary arrest in children.

**What are some of the conditions that can lead to upper airway obstruction in children?**
Evaluation by Organ System: Respiratory System/Airway

- Initial ventilator settings for children
  - Tidal volume 6-10 mL/kg in normal lungs
  - Tidal volume 6 mL/kg in acute lung injury or acute respiratory distress syndrome
  - Respiratory rates in children generally higher than those in adults
Case Study 2

- 2-week-old term neonate presents with nonbilious projectile vomiting and agitation for 3 days
- Last wet diaper 1 day ago
- Fontanelle sunken, mucous membranes dry, and infant appears jaundiced
- T 37°C, HR 190 beats/min, RR 50 breaths/min, BP 44/25 mm Hg

What is the differential diagnosis and most likely etiology?

What initial intervention is indicated?

What diagnostic modalities are indicated?
Evaluation by Organ System: Cardiovascular

- Cardiac output (CO) = HR x SV
- CO is heart rate-dependent
  - Myocardium is noncompliant
  - Minimal change in stroke volume in response to changes in preload and afterload
- Bradycardia is NOT tolerated in infants/children
  - May be sign of significant hypoxemia or acidosis
# Evaluation by Organ System: Cardiovascular

<table>
<thead>
<tr>
<th>Detection</th>
<th>Intervention</th>
<th>Reassessment</th>
<th>Effective Communication</th>
</tr>
</thead>
</table>
| • Evaluate and perform assessment of general appearance, airway, breathing, circulation, pertinent history, and physical exam  | • Provide 100% oxygen  
• Obtain appropriate intravenous/intraosseous access (preferred).  
• Administer appropriate intravenous fluids  
  - 20 mL/kg bolus isotonic crystalloids  
  - Repeat fluid bolus with reassessment  
• Place urinary catheter | • Re-evaluate airway, breathing, circulation, and mental status after each intervention.  
• Repeat fluid at 20 mL/kg  
• Monitor ongoing losses  
• Check the therapeutic end points in resuscitation  
  - End-organ function  
  - Heart rate, blood pressure, signs of perfusion  
  - Mental status  
  - Obtain serum electrolyte measurements, monitor hypo/hypernatremia, acidosis, blood urea nitrogen/creatinine/glucose | • Define team member roles and responsibilities  
• Communicate effectively with other caregivers  
• Promote collegial interaction and knowledge sharing |
Evaluation by Organ System: Cardiovascular (Hypovolemic Shock)

- Most common type of shock in children
- Tachycardia is an early nonspecific sign
- Early recognition before onset of hypotension is critical
  - Children maintain their blood pressures longer in cases of hypovolemia than adults
- Management includes:
  - Aggressive fluid resuscitation
  - Control of ongoing losses (diarrhea, vomiting, hemorrhage)
  - Correction of metabolic/electrolyte derangements
Evaluation by Organ System: Cardiovascular (Distributive Shock)

- Characterized by changes in mental status, fever or hypothermia, and perfusion abnormalities such as vasodilation (warm shock) or vasoconstriction (cold shock)

- Causes
  - Sepsis (most common)
  - Anaphylaxis

- Management
  - Restoration and maintenance of organ perfusion and oxygenation
  - Aggressive fluid resuscitation
  - Vasopressor (norepinephrine) support in fluid-refractory shock
Evaluation by Organ System: Cardiovascular (Cardiogenic Shock)

- Pump failure: decreased systolic function and cardiac output
- Newborns with ductal-dependent lesions (e.g., coarctation of aorta, transposition of the great vessels, tricuspid atresia) may present in cardiogenic shock
  - Administer PGE$_1$ (0.05-0.1 mcg/kg/min) to newborns in shock until a ductal-dependent lesion can be ruled out
- Nonductal-dependent lesions can present beyond newborn period with a history of tachycardia, gallop, murmur, tachypnea, hepatomegaly, and failure to thrive
Evaluation by Organ System: Cardiovascular (Obstructive Shock)

- Obstruction to blood flow (e.g., pulmonary embolism, cardiac tamponade, and tension pneumothorax)
- Uncommon in children
Case Study 3

- 2 year-old male with vomiting, diarrhea for 1 week
- T 37.5°C, HR 150 beats/min, RR 20 breaths/min, BP 70/50 mm Hg
- Lethargic, dry mucous membranes and poor skin turgor on physical examination
- Tonic-clonic seizures broken with rectal diazepam

What is the most likely etiology of seizures?

What is your initial management strategy?

What diagnostic modalities are indicated?
**Evaluation by Organ System: Metabolism/Temperature**

**Pediatric Management of Water and Electrolyte Abnormalities**

| Detection | Evaluate and perform assessment of general appearance, airway, breathing, circulation, pertinent history, and physical exam.  
 | Attach appropriate monitoring devices.  
 | Recognize the respiratory physiology disorder and type of dehydration (normotonic), and categorize the severity |
|---|---|---|
| Intervention | Provide ventilation with bag-mask with 100% oxygen.  
 | Obtain appropriate intravenous/intraosseus access (preferred)  
 | – Administer appropriate intravenous fluids  
 | – 20-mL/kg bolus of isotonic crystalloids  
 | – Repeat fluid boluses with reassessment  
 | Place urinary catheter  
 | Obtain serum electrolytes measurements; monitor hypo-/hypernatremia, calcium, and glucose |
| Reassessment | Reevaluate airway, breathing, circulation, and mental status after each intervention  
 | Repeat fluid at 20 mL/kg if needed  
 | – Correct confirmed hyponatremia with 3% saline to bring sodium >120 mmol/L. Start 3% saline 3 mL/kg over 15 min  
 | – Administer lorazepam 0.05 mg/kg if patient actively having a seizure |
| Effective Communication | Define team member roles and responsibilities  
 | Communicate effectively with other team members and pediatric intensive care unit  
 | Promote collegial interaction and knowledge sharing |
Evaluation by Organ System: Metabolism/Temperature (Water)

- Estimating fluid requirements

<table>
<thead>
<tr>
<th>Body weight</th>
<th>Fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 kg</td>
<td>100 mL/kg/day</td>
</tr>
<tr>
<td>11-20 kg</td>
<td>1000 mL + 50 mL/kg for each kg above 10 kg</td>
</tr>
<tr>
<td>&gt;20 kg</td>
<td>1500 mL + 20 mL/kg for each kg above 20 kg</td>
</tr>
</tbody>
</table>

- Use isotonic fluids (5% dextrose in normal saline, 5% lactated Ringer solution) in hospitalized patients to prevent development of hyponatremia
Evaluation by Organ System: Metabolism/Temperature (Glucose)

- Hypoglycemia more common in infants during stress
  - Low glycogen stores
  - Increased metabolic rate
  - Bedside glucose testing for any child presenting in distress

- Treatment
  - 10% glucose 0.5-1 g/kg (or 5-10 mL/kg) in neonates
  - 25% glucose (2-4 mL/kg) in older children
Evaluation by Organ System: Metabolism/Temperature (Sodium)

- **Hyponatremia**
  - Sodium <135 mmol/L
  - Symptoms include irritability, poor feeding, nausea/vomiting, lethargy, seizures, coma/death (if untreated)
  - Treatment with hypertonic saline: 2% or 3%

- **Hypernatremia**
  - Sodium >145 mmol/L
  - Calculation of free water deficit important in treatment
  - Serum sodium lowered no faster than 0.5 mmol/L/h over 48-72 h
Treatment of hyperkalemia

If significant electrocardiographic abnormalities are presented (peaked T waves, QRS widening, PR-interval prolongation):

- Administer calcium gluconate (10%) 50 mg/kg intravenously OR
- Administer calcium chloride (10%) 10 mg/kg intravenously via central line

For redistribution of potassium:

- Administer sodium bicarbonate 1 mmol/kg intravenously AND/OR
- Administer 25% dextrose 2-3 mL/kg (0.5-1 g/kg) + regular insulin 0.1 U/kg intravenously (IU for each 5 g dextrose)
- Administer inhaled beta-2-agonist (albuterol 2.5-5 mg per dose has been used successfully)

To remove potassium:

- Administer loop diuretic: furosemide 0.5-1 mL/kg
- Administer sodium polysterene sulfonate 1 g/kg per dose orally/rectally every 6 h
- Perform dialysis
Evaluation by Organ System: Immune System

What are some of the factors that place neonates at risk for infections?

- Prompt evaluation and empiric antibiotics important in all neonates presenting with fever
- Understanding of organisms associated with life-threatening infections in different age groups of pediatric patients aids in selection of appropriate antibiotic treatment
# Evaluation by Organ System: Nervous System

## Glasgow Coma Scale Modified for Infants and Children

<table>
<thead>
<tr>
<th>Clinical Parameter</th>
<th>Infants (Ages 0-12 months)</th>
<th>Children (ages 1-5 years)</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eye Opening</strong></td>
<td>Spontaneous</td>
<td>Spontaneous</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Response to speech</td>
<td>Response to speech</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Response to pain</td>
<td>Response to pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>No response</td>
<td>1</td>
</tr>
<tr>
<td><strong>Verbal Response</strong></td>
<td>Coos/babbles</td>
<td>Appropriate words</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Irritable cries</td>
<td>Inappropriate words</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Cries</td>
<td>Persistent cry</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Moans</td>
<td>Grunts</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>No response</td>
<td>1</td>
</tr>
<tr>
<td><strong>Best Motor Response</strong></td>
<td>Normal</td>
<td>Spontaneous</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Withdraws to touch</td>
<td>Localized pain</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Withdraws from pain</td>
<td>Withdraws from pain</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Flexor response</td>
<td>Flexor response</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Extensor response</td>
<td>Extensor response</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>No response</td>
<td>1</td>
</tr>
</tbody>
</table>
Questions
Key Points

- Early signs of respiratory distress include tachypnea, grunting, and nasal flaring
- Airway management is the most important step in management of child with respiratory compromise
- Understanding the anatomic differences between infant/child and adult airways is important for successful pediatric intubation
- Initial ventilator settings for children
  - Tidal volume 6-10 mL/kg in normal lungs
  - Respiratory rates in children generally higher than those in adults
Key Points

- Tachycardia is an early finding in children with shock
- Hypotension is a late finding in children with shock
- Early fluid resuscitation with 40-60 mL/kg is important for treatment of hypovolemic shock
- Norepinephrine is indicated in patients with fluid-refractory vasodilatory shock
- Infants with congenital lesions that interfere with cardiac function (e.g., coarctation of aorta or interrupted aortic arch) can present with cardiogenic or (rarely) obstructive shock
Key Points

- Low glycogen stores and higher metabolic rates place infants at risk for hypoglycemia during stress
- Irritability is an early sign of changes in mental status in young children
- Febrile neonates (<2 mo) should receive empiric antibiotics promptly