Overview

I. Shock
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III. Acute Hypertension
IV. Ventilator support
V. Asthma
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VII. Child Abuse
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I. Shock

A. Definition
- Acute energy failure: inadequate ATP to support cellular function
- Lack of oxygen (anemia, hypoxia or ischemia), glucose substrate (glycopenia) or mitochondrial dysfunction (cellular)
- Children are sensitive to small amounts of volume loss due to decreased volume, decreased cardiac reserve (high baseline heart rate, reduced HR compensation for decreased stroke volume)

B. Etiology
- Hypovolemic
- Cardiogenic
- Distributive
- Obstructive: cardiac tamponade, tension pneumothorax, massive pulmonary embolism

C. Clinical presentation (see tables below)
- Inadequate oxygen and nutrient delivery to meet tissue demands
- Compensated shock: perfusion to vital organs maintained, hard to detect, tachycardia may be present
- Decompensated shock: poor perfusion, tachycardia, hypotension, lethargy

D. Resuscitation
- Peripheral, interosseous, umbilical access
- Isotonic crystalloid bolus 20 ml/kg until endpoints met
- Ionotropes/vasopressors if refractory
- Consider hydrocortisone for suspected adrenal insufficiency

E. End-points of resuscitation
- Age appropriate pulse pressure, heart rate, respiratory rate
- Cardiac index > 2
- SVO2 > 70%
- Anion gap < 16, lactate < 2 mmol/l
- Urine output > 1 ml/kg/h
<table>
<thead>
<tr>
<th>System</th>
<th>Compensated Shock, Mild Hemorrhage, Simple Hypovolemia (&lt;30% blood volume loss)</th>
<th>Decompensated Shock, Moderate Hemorrhage, Marked Hypovolemia (30%–45% blood volume loss)</th>
<th>Cardiopulmonary Failure, Severe Hemorrhage, Profound Hypovolemia (&gt;45% blood volume loss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular</td>
<td>Mild tachycardia</td>
<td>Moderate tachycardia</td>
<td>Severe tachycardia</td>
</tr>
<tr>
<td></td>
<td>Weak peripheral pulses</td>
<td>Thready peripheral pulses</td>
<td>Absent peripheral pulses</td>
</tr>
<tr>
<td></td>
<td>Strong central pulses</td>
<td>Weak central pulses</td>
<td>Thready central pulses</td>
</tr>
<tr>
<td></td>
<td>Low-normal blood pressure (SBP &gt;70 mmHg + [2? age in years])</td>
<td>Frank hypotension (SBP &lt;70 mmHg + [2? age in years])</td>
<td>Profound hypotension (SBP &lt;50 mmHg)</td>
</tr>
<tr>
<td></td>
<td>Mild acidosis</td>
<td>Moderate acidosis</td>
<td>Severe acidosis</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Mild tachypnea</td>
<td>Moderate tachypnea</td>
<td>Severe tachypnea</td>
</tr>
<tr>
<td>Neurologic</td>
<td>Irritable, confused</td>
<td>Agitated, lethargic</td>
<td>Obtunded, comatose</td>
</tr>
<tr>
<td>Integumentary</td>
<td>Cool extremities, motting</td>
<td>Cool extremities, pallor</td>
<td>Cold extremities, cyanosis</td>
</tr>
<tr>
<td></td>
<td>Poor capillary refill (&gt;2 sec)</td>
<td>Delayed capillary refill (&gt;3 sec)</td>
<td>Prolonged capillary refill (&gt;5 sec)</td>
</tr>
<tr>
<td>Excretory</td>
<td>Mild oliguria, increased specific gravity</td>
<td>Marked oliguria, increased blood urea nitrogen</td>
<td>Anuria</td>
</tr>
</tbody>
</table>

- **0 min** Recognize decreased mental status and perfusion. Maintain airway and establish access according to PALS guidelines.
- **5 min** Push 20 mL/kg isotonic saline or colloid boluses up to and over 60 mL/kg. Correct hypoglycemia and hypocalcemia.
- **15 min** Fluid-responsive shock. Establish central venous access, begin dopamine therapy, and establish arterial monitoring.
- **60 min**
  - **Normal blood pressure**
  - **Low blood pressure**
  - **Cold shock**
  - **Svo2 sat <70%**
  - Add vasodilator or type III PDE inhibitor with volume loading.
  - **Titrate epinephrine for cold shock and norepinephrine for warm shock to normal MAP – CVP and Svo2 saturation >70%**
  - **Catecholamine-resistant shock**
  - **At risk of adrenal insufficiency?**
  - **Give hydrocortisone**
  - **Not at risk?**
  - **Do not give hydrocortisone**
  - **Consider ECMO**
<table>
<thead>
<tr>
<th>Type of Shock</th>
<th>HR</th>
<th>Preload</th>
<th>Contractility</th>
<th>SVR</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypovolemic</td>
<td>↑</td>
<td>↓↓</td>
<td>+/-</td>
<td>↑</td>
<td>• High flow oxygen</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Fluid resuscitation: evaluate perfusion after 60 mL/kg total volume</td>
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<td></td>
<td>bolused, then consider pressors</td>
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<tr>
<td>Septic (early, warm)</td>
<td>↑</td>
<td>↓↓</td>
<td>+/-</td>
<td>↓</td>
<td>• High flow oxygen</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>• Fluid resuscitation</td>
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<td></td>
<td>• Antibiotics</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Pressors (dopamine, norepinephrine, phenylephrine)</td>
</tr>
<tr>
<td>Septic (late, cold)</td>
<td>↑</td>
<td>↓↓</td>
<td>↓</td>
<td>↑</td>
<td>• High flow oxygen</td>
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<td>• Fluid resuscitation</td>
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<td>• Antibiotics</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Pressors (dopamine, epinephrine, phenylephrine)</td>
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<tr>
<td>Anaphylactic</td>
<td>↑</td>
<td>↓↓</td>
<td>↓</td>
<td>↓</td>
<td>• High flow oxygen</td>
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<tr>
<td></td>
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<td></td>
<td>• Epinephrine (IM)</td>
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<td></td>
<td></td>
<td></td>
<td>• Fluid resuscitation</td>
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<tr>
<td>Neurogenic</td>
<td>↑</td>
<td>↓↓</td>
<td>+/-</td>
<td>↓↓</td>
<td>• Fluid resuscitation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Pressors (norepinephrine)</td>
</tr>
<tr>
<td>Cardiogenic</td>
<td>↑</td>
<td>↑</td>
<td>↓↓</td>
<td>↑</td>
<td>• High flow oxygen</td>
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<tr>
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<td></td>
<td>• Fluid resuscitation (5–10 mL/kg)</td>
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<td></td>
<td></td>
<td>• CHF management (CPAP/BiPAP, diuretics, ACE inhibitors)</td>
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<tr>
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<td></td>
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<td></td>
<td></td>
<td>• Inotropes (milrinone, dobutamine)</td>
</tr>
<tr>
<td>Obstructive</td>
<td>Cause dependent</td>
<td>Cause dependent</td>
<td>Cause dependent</td>
<td>Cause dependent</td>
<td>• Therapy directed at primary etiology of shock</td>
</tr>
</tbody>
</table>
II. Cardiac Arrest: four phases

A. Epidemiology
   - Most frequently from respiratory failure
   - SIDS most common cause out-of-hospital cardiac arrest
   - Most in-hospital cardiac arrest have primary cardiac disease
   - CPR outcome: 5-10% survival to hospital discharge
   - 10-80% of survivors have significant neurologic disability

B. Pre-arrest (protect)
   - Optimize community education on child safety
   - Optimize patient monitoring
   - Avoid progression of respiratory failure and/or shock to cardiac arrest

C. No-Flow (preserve)
   - Minimize interval to defibrillation
   - Preserve cardiac and cerebral substrate

D. Low flow (resuscitate)
   - Successful CPR: push hard/push fast
   - Titrate CPR to end-tidal CO₂ or pulse pressure
   - High dose epinephrine (0.05-0.2 mg/kg) NOT recommended for initial or rescue therapy
   - Consider mechanical devices/ECMO if no return of circulation following 20-110 minutes CPR
   - Shock resistant VF should be treated with amiodarone

E. Post-resuscitation: high risk of continuing brain injury, ventricular arrhythmias, reperfusion injury
   - Optimize cardiac/cerebral perfusion
   - Resuscitative systemic hypothermia (24-48 hours)
   - Avoid hyperglycemia/hyperthermia/hyperventilation
   - Early occupational/physical therapy

III. Ventilatory support

A. Volume limited
   - Delivers preset tidal volume regardless of pressure required
   - Risk for barotraumas
   - Alarms and pop-off valves that limit peak inspiratory pressure can minimize risk of barotrauma

B. Pressure limited
   - Gas flow delivered until preset pressure is reached
• Gas flow delivery held for set inspiratory time
• Reduces risk of barotrauma
• Useful for neonatal and infant support (<10 kg)
• Permits delivery of small tidal volumes

C. **High frequency ventilation**
   • High frequency oscillatory ventilation (HFOV)
     o High amplitude and high frequency
     o Tidal volumes less than dead space
     o Bias gas flow maintains airway pressure
     o Minimizes barotrauma and oxygen toxicity
     o **Insure patients euvolemic due to risk for decreased venous return**
   • High frequency jet ventilation
     o Used simultaneously with a conventional ventilator
     o Jet injector port delivers short bursts of inspiratory gas
     o Adequate gas exchange at low airway pressures
     o Maintains lung volumes and minimizes barotrauma

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**IV. Acute Hypertension**

A. **Assessment**
   • Use appropriate cuff size; correlate with BP tables for age, height, weight
   • Hypertensive urgency: BP elevation without end-organ damage. More common in children
     o Symptoms: Headache, blurred vision, nausea
     o Lower MAP by 20% over 1 hour and return to baseline over 24 to 48 hours
   • Hypertensive emergency: elevation of BP with acute end-organ damage
     o cerebral infarction/hemorrhage, pulmonary edema, renal failure, encephalopathy, seizures
     o **Rule out hypertension secondary to elevated ICP before lowering BP**
     o Lower MAP by 1/3 over first 6 hours, then 1/3 over next 24-36 hours, then final 1/3 over next 48 hours
   • Physical Examination
     o Four extremity BP, funduscopy, CV, neuro
     o Diagnostic evaluation: BUN/Cr, electrolytes, abdominal ultrasound, head CT, renal Doppler ultrasound

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**V. Asthma**

A. **Pathophysiology**
   • Most common cause of respiratory distress and failure
   • Bronchoconstriction, epithelial cell injury-mediated neurogenic inflammation, luminal obstruction from secretions and cellular debris
   • Progressive dynamic hyperinflation
Pulmonary edema: increase RV afterload, decreased LV preload, decreased cardiac output

B. Evaluation
- General appearance, respiratory rate, degree of tachycardia, oxygen saturation
- Severe distress: lethargy, agitation, orthopnea, fragmented speech, use of accessory muscles, silent chest due to poor air movement
- Metabolic acidosis from dehydration, lactic acid production from respiratory musculature or cardiac failure

C. Pharmacotherapy
- Oxygen: mask, tent, nasal cannula supplemented face mask
- Inhaled bronchodilators (β-2 agonists) to reduce hypoxic pulmonary vasoconstriction
- Continuous albuterol (20 mg/hr max) may be needed
- Ipratropium bromide acts on muscarinic receptors, synergistic to β-2 – agonists (200-500 ug every 6-8 hours)
- Subcutaneous β-2-agonists may be needed in initial management
- Methylprednisolone reduces mucus production and inflammation
- Helium-oxygen promotes laminar flow but loses effectiveness at FiO2 > 50%

D. Ventilatory support
- Indications: cardiopulmonary arrest, respiratory failure
- Trial of non-invasive ventilation while preparing for intubation
- Pre-intubation volume loading, topical aerosolized lidocaine, pre-oxygenation
- Control tidal volume and respiratory rate to minimize dynamic hyperinflation

E. Refractory Disease
- ECMO should be considered for life-threatening hypoxemia; survival is high, morbidity minimized with veno-venous techniques
- Bronchoscopy only if airway obstruction from mucus/debris not responsive to mucolytics
- Respiratory acidosis can be managed with tromethamine

F. Morbidity
- Nosocomial infections: minimize by attention to detail
  - Hand washing
  - Transpyloric feeding
  - Sterile technique for all procedures
- Post-traumatic stress disorder
- Opioid/benzodiazepine dependence
• Altered sleep patterns
• Myopathy/rhabdomyolysis
• Deconditioning
• Deep venous thrombosis

VI. Increased Intracranial Pressure (ICP)

A. Assessment
• History: trauma, vomiting, fever, headache, neck pain, visual change. In infants: irritability, vomiting, poor feeding, lethargy, bulging fontanel
• Physical exam/laboratory evaluation
• Management:
  o Elevate HOB 30° (if not contraindicated)
  o Head CT
  o Normal saline or hyperosmolar solutions
    ▪ 3% NaCL, 2-5 ml/kg or mannitol 0.25 g/kg IV
    ▪ Hyperventilation for acute management only (pCO₂ 30-35 mmHg)
  o DO NOT LOWER BLOOD PRESSURE
  o Prevent hyperthermia
  o Dexamethasone to reduce cerebral edema in space-occupying lesions
  o Keep MAP > ICP
  o Avoid hypotension, hypoxia, hypercarbia, hypovolemia

PITFALL

VII. Child Abuse

• Multidisciplinary approach: medical professionals, social worker, community agencies
• Correlate physical findings with history
• Shapes of bruises important: be suspicious of bruises in protected areas (buttocks, chest, abdomen, back)
• Retinal hemorrhages are pathognomonic of abusive head trauma
• Skeletal survey mandatory in children < 2 years with suspicious fractures
• Treat: medical stabilization primary goal
• Report: All healthcare workers who suspect child maltreatment must report to local police and/or child welfare agency
• Document: legible, include word-for-word history, drawings of injuries including shape, location, size, color

PEARL

VIII. Brain Death

• Determine if treatable causes of coma exist (hypothermia, toxic/metabolic states, hypotension)
• Physical Exam (see algorithm)
  o Requires age dependent observation period between 2 exams
  o Coexistent coma and apnea
  o Loss of volitional ability
Absent brainstem function
Consistent exam throughout observation period

<table>
<thead>
<tr>
<th>Age</th>
<th>Hours Between 2 Examinations</th>
<th>Recommended Number of EEGs</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 days-2 months</td>
<td>48</td>
<td>2</td>
</tr>
<tr>
<td>2 months-1 year</td>
<td>24</td>
<td>2</td>
</tr>
<tr>
<td>&gt;1 year</td>
<td>12</td>
<td>Not needed</td>
</tr>
</tbody>
</table>

IX. End of Life Care

A. Analgesia
   - Document signs and symptoms of suffering and rationale of the regimen chosen to treat
   - Titrate to effect; no theoretical or practical maximal dose

B. Doctrine of double effect
   - The action must be good or morally indifferent
   - The agent must intend only the good effect and not the bad
   - The bad effect cannot be a means to the good effect
• The good that is intended must outweigh the bad that is permitted
• Viable alternatives to double-effect reasoning in guiding care of patients dying in the ICU are limited

X. **Law and ethics**

A. **Overview**
• Most deaths in the PICU occur following withdrawal of care
• Parents have the authority to determine the best interests of their children
• Children should participate in decision-making commensurate with their development and should not be excluded from decision-making
• Children should provide assent to care whenever reasonable

B. **Assent**
• Helping the patient achieve appropriate awareness of the nature of his/her condition
• Telling the patient what to expect with tests/treatments
• Assess the patient's understanding of the situation
• Solicit an expression of the patient's willingness to accept the proposed care

C. **Baby Doe regulations**
• State regulator system to investigate cases in which medically indicated treatment is withheld from handicapped infants
• Regulatory stature; no strong clinical application
• Withholding medically indicated treatment from a disabled infant with a life-threatening condition is considered medical neglect.
• Exceptions:
  o Infant is chronically and irreversibly comatose
  o Treatment would prolong dying
  o Treatment would be futile in terms of survival