Running on Empty

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Outline

- What is shock?
- Examine differences between kids and adults
- Management
- Case review
## Importance

- All healthcare professionals who care for children will be faced with a child in shock
- Without appropriate intervention, death will ultimately occur
- Early recognition is *imperative*

## What is Shock?
Historical Definitions

- In 1872, “a rude unhinging of the machinery of life”
- “A momentary pause in the act of death”
- Most recently, “the collapse and progressive failure of the cardiovascular system.”

Shock

- Acute process
- Complex series of events
- Reduced perfusion of vital organs → inadequate oxygen and nutrients necessary for normal tissue and cellular function
- Reduction of mitochondrial oxygen → anaerobic metabolism and production of lactic acid
Complex Series of Events

Untreated Shock
Types of Shock

- Hypovolemic – the focus of this lecture
- Distributive – septic and neurogenic
- Cardiogenic

Hypovolemic Shock

- *Decreased circulating blood volume*
- Most *common* cause of shock in children
- Due to blood, water or plasma losses
Common Causes

- Trauma ➔ hemorrhage
- Intracranial or GI bleed
- Vomiting and diarrhea
- Burns
- Pregnancy-related
- Peritonitis
- Sunstroke

Sources of Blood Loss from Trauma

- Scene
- Chest
- Abdomen
- Retroperitoneal
- Muscle compartments
Hemorrhagic Shock

- Divided into 4 classes
- Based on signs, symptoms and estimated degree of blood loss

| Classification of Hemorrhagic Shock in PEDIATRIC Trauma Patients based on Systemic Signs |
|-----------------------------------------------|-------------------------------------------------|
| Class I                                      | Class II                                        | Class III                                    | Class IV                                    |
| Very little hemorrhage (81% blood volume loss) | Moderate hemorrhage (15%–25% blood volume loss) | Severe hemorrhage (0%–39% blood volume loss) | Critical hemorrhage (>40% blood volume loss) |
| Cardiorespiratory                             | Respiratory                                     | Central nervous                                | Kidneys                                      |
| Hypotension, tachycardia                      | Hypoxia, tachypnea                              | Hypotension, tachycardia                       | Oliguria, increased specific gravity         |
| Normal pulse                                 | Normal or mildly decreased                      | Severe tachycardia                            | Oliguria, decreased BUN                     |
| Tachycardia                                  | Hypoxia                                         | Moderate tachycardia                           | Anuria                                       |
| Hypoxia, tachypleo                           | Severe tachycardia                              | Severe tachypleo                              |                                             |
| Moderate or severe tachypleo                 | Lactic acidemia                                 | Lactic acidemia                               |                                             |
| Lactic acidemia                              | Intolerable or lactic acidemia                  | Intolerable or lactic acidemia                |                                             |
| Corneal opacity                              | Unexplained                                     | Unexplained                                   |                                             |
| Capillary refill delay                       | Capillary refill delay                          | Capillary refill delay                        |                                             |
| Capillary refill delay                       | Capillary refill delay                          | Capillary refill delay                        |                                             |
| Capillary refill delay                       | Capillary refill delay                          | Capillary refill delay                        |                                             |


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Pediatric Shock

- Difficult to recognize for clinicians who do not primarily care for children
- In trauma patients, assessment of circulation is often overlooked

Just One Drop

- *Journal of Trauma, 2010*
- Temple University, Department of Surgery
- Prospective study in adult trauma patients
- *A single, isolated hypotensive event during a trauma resuscitation was indicative of severe injuries and the need for operative intervention.*
- *Hypotensive events should NOT be ignored*
## Pediatric Trauma Care

- *No different than adult trauma care*
- Must consider unique aspects of a child
- Many differences compared to adults
  - Anatomic
  - Physiologic
  - Psychologic

## How are kids different?
Smaller in size, but not just little adults
Anatomic Differences

- Shorter neck and trachea
- Larger face to head ratio
- Large tongue and tonsils
- Anterior/superior larynx
- Narrowest point at subglottic region
- Resembles adult by age 8
Head

- Thinner calvarium
- Open sutures
- Large scalp surface area
- Weaker neck muscles

Cervical Spine

- Fulcrum of spine is C2-C3
- Children < 14 yo have higher injuries
- Children > 14 yo have lower injuries
- Resembles adult by age 8
### Chest

- More compliant chest wall
- More anterior position of the heart
- More mobile mediastinal structures

### Abdomen

- Relatively larger abdomen
- Relatively larger organs
- Underdeveloped wall musculature
Skeleton

- More pliable bones
- Incomplete calcification
- Multiple ossification centers

Physiologic Differences
## Perfusion

- *Relatively* larger blood volume
- Stroke volume is essentially fixed
- Cardiac output maintained by HR
- Increased sensitivity to catecholamines
- Increased arterial vascular tone

![Perfusion Diagram](image)

## Review of Cardiac Output

- Determined by SV and HR
- SV depends on contractility, SVR, and ventricular filling volume
- *Children increase HR rather than SV in times of metabolic need (shock)*

\[
\text{CO (L/min)} = \text{SV (cc/beat)} \times \text{HR (beats/min)}
\]
## Tachycardia

- **Most sensitive** indicator in pediatric shock
- **Not specific**
- Complete PE necessary to rule out shock as cause of tachycardia

## Kids are Different

- Abundant physiologic reserve
- Demonstrate few signs of hypovolemia
- *Hypotension is a late sign of shock*
Take home messages

- Children can lose > 40% of their blood volume before they have a blood pressure change
- *Children can be in shock and have a normal BP*
Estimating Blood Volume

Pediatric Blood Volume

- 80 ml/kg
- Estimating Blood Volume: Weight (kg) X 80 ml/kg
12kg x 80 ml/kg = 1L blood volume

1 liter NS

12kg x 80 ml/kg = 1L blood volume
25 kg \times 80 \text{ ml/kg} = 2000 \text{ ml}

25 kg \times 80 \text{ ml/kg} = 2000 \text{ ml}
Estimating blood loss

- Calculate the blood volume (15 kg child)
- 15 kg child x 80 ml/kg = 1200 ml
- 30% blood loss x 1200 ml = 360 ml of blood

or....
15 kg x 80 ml/kg = 1200 ml x 30% = 360 ml
Thermoregulation

- High BSA-to-mass ratio
- *Increases the risk of hypothermia and dehydration*
- Hypothermia increases morbidity and mortality

Psychological Differences
Psychological

- Fairly predictable based on age
- Family presence extremely important
- Caretakers can aid with assessing mental status

Management of Shock
Goals

- Restore substrate delivery, mainly oxygen to the tissues
- Preserve brain and kidney function
- Control bleeding in trauma patients

Shock Management

- Requires functioning pump
- Adequate blood volume
- Intact vascular system
- Normothermia
- Recognition
Pediatric Assessment

*80% of your pediatric evaluation is based on observation alone

Circulation

- Requires rapid, accurate assessment
- Clinical observation of 3 components:
  - Level of consciousness
  - Skin color
  - Pulses (central vs. peripheral)
  - Fluid resuscitation
## Running on Empty

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### Traditional Approach

- **Adults:** 2-3 liters of crystalloid  
- **Pediatrics:** 40-60 ml/kg of crystalloid
Responses to Resuscitation

Table 2—Responses to Initial Fluid Resuscitation

<table>
<thead>
<tr>
<th></th>
<th>RAPID RESPONSE</th>
<th>TRANSIENT RESPONSE</th>
<th>NO RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital signs</td>
<td>Return to normal</td>
<td>Transient improvement, recurrence of ↓ BP and ↑ HR</td>
<td>Remain abnormal</td>
</tr>
<tr>
<td>Estimated blood loss</td>
<td>Minimal (10%–20%)</td>
<td>Moderate and ongoing (20%–40%)</td>
<td>Severe (&gt;40%)</td>
</tr>
<tr>
<td>Need for more crystalloid</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Need for blood</td>
<td>Low</td>
<td>Moderate to high</td>
<td>Immediate</td>
</tr>
<tr>
<td>Blood preparation</td>
<td>Type and crossmatch</td>
<td>Type-specific</td>
<td>Emergency blood release</td>
</tr>
<tr>
<td>Need for operative</td>
<td>Possibly</td>
<td>Likely</td>
<td>Highly likely</td>
</tr>
<tr>
<td>intervention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early presence of surgeon</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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</table>

2000 mL Ringer’s lactate solution in adults, 20 mL/kg Ringer’s lactate bolus in children.

Advantages of Crystalloids

- Increase circulation to the brain and kidneys
- Readily available in the pre-hospital setting
- Circulation of blood we do have in the vascular system
Drawbacks

- May increase hemorrhage and/or disrupt clots by increasing BP
- Do not contain the components of whole blood
- May dilute clotting factors
- No oxygen-carrying capacity

Case review

For each case:
- GOOD = rapid response
- BAD = transient response
- UGLY = no response
## Case 1

- 10 year old boy riding “BMX” bicycle
- Falls while attempting aerial maneuver
- Arrives in at outside hospital complaining of vague abdominal pain
- CT scan negative
- Sent home

## Case 1 continued

- Arrives at your hospital 2 days later
- Awake, alert, oriented
- Weight = 40 kg
- 24 hour history of vomiting
- Diffuse abdominal pain, tender
- Heart rate 120, respiratory rate 16, blood pressure 125/80, capillary refill 5 seconds
- What would you do?
Case 1 continued

- What is this patient's blood volume?
- What is this patient's hemodynamic status (good, bad, or ugly)
- Does this patient need a fluid bolus?
- What do you suspect is the problem?
Case 1 continued

• What is this patient’s blood volume?
  • Roughly 3.2 liters
• What is this patient’s hemodynamic status (good, bad, or ugly)
• Does this patient need a fluid bolus?
• What do you suspect is the problem?

Case 1 continued

• What is this patient’s blood volume?
  • Roughly 3.2 liters
• What is this patient’s hemodynamic status (good, bad, or ugly)
  • Bad (tachycardic, poor cap refill)
• Does this patient need a fluid bolus?
• What do you suspect is the problem?
### Case 1 continued

- **What is this patient’s blood volume?**
  - Roughly 3.2 liters
- **What is this patient’s hemodynamic status (good, bad, or ugly)?**
  - Bad (tachycardic, poor cap refill)
- **Does this patient need a fluid bolus?**
  - Yes (800 ml warm Normal Saline)
- **What do you suspect is the problem?**
**Case 2**

- 3 year old playing in yard at dusk
- Brother cutting lawn on riding mower
- Runs over child causing several leg wounds
- Local EMS unit calls for helicopter
- Wounds are wrapped

<table>
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<tr>
<th>3 year old playing in yard at dusk</th>
<th>Brother cutting lawn on riding mower</th>
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<tbody>
<tr>
<td>Runs over child causing several leg wounds</td>
<td>Local EMS unit calls for helicopter</td>
</tr>
<tr>
<td>Wounds are wrapped, IV started, 150 ml bolus given, morphine 0.1 mg/kg IV</td>
<td>Weight is 15 kg</td>
</tr>
</tbody>
</table>
Case 2

- On arrival, pulse is 110, BP is 90/50, he is crying softly and awake
- Because of contamination in the wounds and associated fractures, the orthopedic team wants to take the patient to the OR ASAP.

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Case 2

What is his blood volume?

What is the correct fluid bolus?

What should you worry about when team ortho takes him to the OR?
## Case 2

**What is his blood volume?**
- 1200 ml

**What is the correct fluid bolus?**

**What should you worry about when team ortho takes him to the OR?**

**Is this patient good, bad, or ugly?**

- 300 ml of WARM saline
Case 2

He's bad, but could become ugly due to:

- **HYPOTHERMIA**
  - Warm IV fluids
  - Warm O.R. (even if they complain)
  - Forced warm air blankets

- **BLOOD LOSS**
  - Difficult to calculate in ortho environment
  - Consider early transfusion
Case 3

- 15 year old girl brought to emergency department by friend
- No history of trauma
- Distended and tender abdomen
- Previous history of pregnancy (terminated) at age 14
- Approximate weight: 50 kg

Patient extremely agitated “please help me – I’m going to die!”
- Heart rate 155, first blood pressure 80/45, respiratory rate 24
- BP 100/60, HR = 155 after 1 liter of normal saline and 2nd liter initiated
- Bedside ultrasound (by radiologist) shows free fluid in abdomen, enlarged uterus
### Case 3

- Heart Rate > 150 and BP 85/45 after 2\textsuperscript{nd} 1000 ml of IV fluids
- 2 units of PRBC given by rapid infuser through 18 gauge peripheral IV
- Patient remains tachycardic with BP 90/60
- Abdomen appears more distended

### Case 3

- Is this patient
  - Good?
  - Bad?
  - Or Ugly?
Case 3

• Is this patient
  • Good?
  • Bad?
  • Ugly (uncompensated shock, no response to fluids and blood)

Case 3

• Patient taken rapidly to operating room
• Well over 1000 ml of blood in abdomen
• 2 more units of PRBC given in OR
Case 3

- Diagnosis: ruptured ectopic pregnancy
- Treatment:
  - Recognition and management of shock
  - Restoration of blood volume
  - Operative control of bleeding
## Case 3

**Moral:**
The skills that you develop for treating trauma patients (such as recognition of shock) can help you treat other patients

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## Conclusion

Recognition of shock is based on vital signs and physical findings

“When all else fails, examine the patient”