Summary of "Emergency Department Management of Pediatric Shock"
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Introduction

- Shock is a state of inadequate oxygen supply to meet the body's cellular demands.
- In children, compared with adults, cardiac output is more dependent on heart rate than stroke volume owing to myocardial immaturity, which limits the ability to increase contractility.
- In compensated shock, as in exercise, increased oxygen demand or decreased oxygen delivery (shock), initial compensatory mechanisms occur to preserve tissue perfusion.
- In compensated shock, blood pressure remains normal.
- In uncompensated shock, hypotension develops and organ and cellular function deteriorate.

Classifications of shock

Table 1
Categories of shock

Category	Hemodynamics	Causes
Hypovolemic	↓Preload, ↑SVR, ↓CO	Gastrointestinal loses, renal loses, hemorrhage, third spacing, burns
Distributive	↓Preload, ↓↓SVR, ↓↑CO	Sepsis, anaphylaxis, neurogenic shock
Cardiogenic	↑Preload, ↑SVR, ↓CO	Congenital heart disease, arrhythmia, cardiomyopathy, myocarditis, severe anemia
Obstructive	↓↑Preload, ↑SVR, ↓CO	Pulmonary embolus, pericardial tamponade, tension pneumothorax, certain congenital heart lesions

Abbreviations: CO, cardiac output; SVR, systemic vascular resistance.

Hypovolemic Shock

- Most common cause of shock in children, leading cause of child mortality worldwide.
- Kids with gastroenteritis can lose a significant percentage of their circulating volume within a few hrs.
- For mild to moderate dehydration large studies have shown oral rehydration is highly successful (<5% failure rate) with shorter ED stays and fewer adverse events compared with IV hydration.
- If a patient shows signs of decreased end-organ perfusion, proceed to IV resuscitation.
- Capillary leak syndrome owing to sepsis, burns or other systemic inflammatory diseases can result in profound intravascular volume loss in patients that may otherwise seem to be edematous and volume overloaded.
- Hemorrhagic shock can be divided into stages of severity.

Table 2
Classification of pediatric hemorrhagic shock by clinical signs

	Class I Very Mild Blood Loss (<15%)	Class II Mild Blood Loss (15%–30%)	Class III Moderate Blood Loss (30%–40%)	Class IV Severe Blood Loss (>40%)
HR	Normal to mildly increased	Tachycardic	Tachycardic	Severely tachycardic
Pulse quality	Normal	Peripheral pulses decreased	Peripheral pulses decreased	Central pulses decreased
Respiratory rate	Normal	Tachypneic	Tachypneic	Severely tachypneic
Mental status	Normal/ slightly anxious	Anxious/irritable	Irritable/confused	Confused/lethargic/ obtunded
Urine output	Normal	Decreased	Decreased	Anuric
Skin	Warm/pink	Cool/mottled	Cool/mottled/pallor	Cold/pallor/cyanotic

- In an infant/toddler in shock with unclear etiology, consider occult hemorrhage owing to nonaccidental trauma.

Distributive Shock

- Normal vascular tone becomes inappropriately relaxed. Vasodilation leads to effective hypovolemia although a net fluid loss may not have occurred.
- Common causes:
  - Sepsis- massive inflammatory response along with nitric oxide and cytokine release
  - anaphylaxis- mast cell degranulation leads to vasodilatory cytokine release
  - neurologic injury (spinal shock)- sympathetic chain of autonomic nervous system disrupted resulting in unopposed parasympathetic vasodilation
  - toxicologic
- American College of Critical Care Medicine defines septic shock as a clinical diagnosis made when children have suspected infection manifested by hypothermia or hyperthermia and clinical signs of inadequate tissue perfusion including any of the following: decreased/altered mental status, abnormal capillary refill time (CRT) or pulse characteristic, or decreased urine output (<1 mL/kg/h). Hypotension is not required for the clinical diagnosis of septic shock.
- Septic shock can present in one of two ways: cold shock or warm shock.
- Cold shock is characterized by high SVR resulting in cool/cold extremities, delayed CRT (<2 seconds), diminished peripheral pulses or differential between peripheral and central pulses, and narrow pulse pressure.
- Warm shock is characterized by low SVR, with warm/dry extremities with brisk ("flash") CRT, tachycardia, and bounding pulses with a wide pulse pressure.

Cardiogenic Shock

- In children usually myocarditis or congenital heart disease or a cardiomyopathy
- Categories of heart failure and cardiogenic shock are classified by 2 traits: venous congestion (owing to increased filling pressures) and hypoperfusion (owing to decreased cardiac output or myocardial contractility).

Hemodynamic Profiles in Pediatric Heart Failure

Warm and dry:

- Normal perfusion and no congestion.
- Well-compensated but may have significant cardiac dysfunction.

Cold and dry:

- Poor perfusion (cool extremities, weak pulses, narrow pulse pressure, delayed CRT, AMS, hypotension) without venous congestion. Decompensating.
- Sick appearing. Increased peripheral vascular resistance.
- May have oliguria and altered mental status.

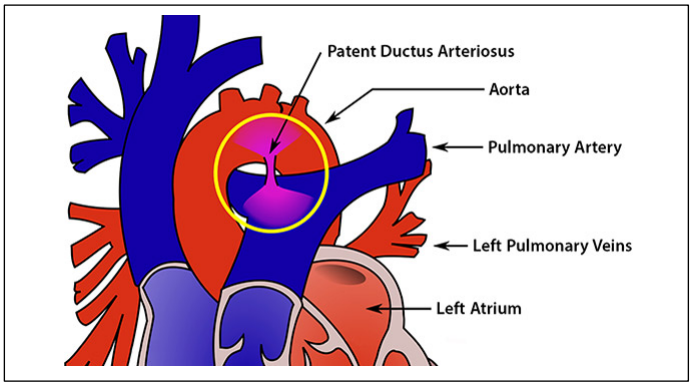
Warm and wet:

- Normal perfusion with venous congestion (edema, rales, ascites, JVD, S3 gallop)
- Still partially compensated.
- May benefit from diuretics or inodilators.

Cold and wet:

- Poor perfusion with venous congestion.
- The sickest group of all.
- Usually requires inotropes.
- May require mechanical support.

Obstructive Shock



- Either pulmonary or systemic blood flow is impaired resulting in impaired cardiac output.
- May be intracardiac or extracardiac obstruction and may be congenital or acquired.
- Examples: tamponade, pneumothorax, massive PE, severe pulmonary hypertension, hypertrophic cardiomyopathy, obstructive congenital lesions
- In infants, obstructive shock occurs when congenital lesions obstruct outflow of blood from the heart, requiring the systemic output to be supplied by the pulmonary artery system via the ductus arteriosus.
- When the ductus closes in the first few days or weeks after birth the infants present with severe shock.
- Obstructive shock requires prompt recognition and intervention (eg , prostaglandin therapy for a ductal-dependent lesion, pericardiocentesis for tamponade, thoracostomy for pneumothorax.

Recognition

- All infants under 3 mos presenting in shock are septic until proven otherwise.
- The history of a child in shock is often nonspecific with symptoms such as lethargy, fussiness, poor feeding or decreased urine output.
- Children compensate for shock with tachycardia and increased SVR.
- Tachycardia is the most common presenting physical exam finding.
- Increased SVR manifests as delayed capillary refill time (CRT), diminished peripheral pulses.
- Prolonged CRT is highly specific but not sensitive for mortality.
- Prolonged CRT and hypotension portend a 26.9 mortality rate.
- Hypotension is defined as <5th percentile for age.

Table 3
Pediatric heart rate ranges and hypotensive systolic blood pressure levels by age

Age	HR (bpm)	Hypotensive SBP (mm Hg)
<1 mo	110–180	<60
1–12 mo	100–170	<70
1–2 y	85–150	<70 + (2 × age in y)
3–5 y	70–140	<70 + (2 × age in y)
6–10 y	60–110	<70 + (2 × age in y)
>10	50–100	<90

Ultrasound Exam

Evidence for use of POCUS in pediatric shock lags behind adults.

Treatment

- Every child in shock should get supplemental oxygen.
- Continuous cardiorespiratory and pulse oximetry monitors.
- Peripheral IV access
- Check blood sugar and correct hypoglycemia.

- Hypocalcemia (ionized calcium<1.1 mmol/L) should also be corrected.

Fluid Resuscitation

- **Treat signs of shock with a 20ml/kg bolus, even if BP normal, and give repeated boluses if systemic perfusion fails to improve.**
- In neonates or suspected cardiogenic shock, use 10ml/kg boluses and reassess frequent for signs of volume overload (hepatomegaly, S3 gallop, pulmonary rales.
- Volume resuscitation in hypovolemia and sepsis requires 40-60ml/kg and may require as much as 200ml/kg.
- **Start vasopressors for children in shock after 60ml/kg of IV fluids.**
- Fluid administration in shock should be as rapid as possible. This can be achieved with a push/pull technique using a 3 way stopcock and a large syringe or using a pressure bag (the two methods have been shown to be equivalent).
- 20ml/kg of fluid can be administered in 5 minutes or less via pressure bag or push methods.
- Central line unnecessary in children, at least in the initial stages. Peripheral or IO lines are fine.

Vasoactive Medications

- Start vasopressors through whatever line is available (peripheral, IO, CVL).
- Extravasation rare in 2017 pediatric study (2%) with none requiring medical or surgical intervention.
- If peripheral iv used, dilute the vasopressor and check the line frequently.
- **Epinephrine now the first line vasopressor for cold fluid-refractory** shock with dopamine reserved when epinephrine is unavailable.

Box 2
Usual dosing ranges for vasoactive medications

Inotropes

Epinephrine 0.05 to 1.00 (or more) μg/kg/min

Dopamine: 5 to 20 μg/kg/min

Dobutamine 5 to 20 μg/kg/min

Vasopressors

Norepinephrine 0.05 to 0.50 (or more) μg/kg/min

Dopamine 10 to 20 μg/kg/min

Vasopressin 0.0005 to 0.0100 U/kg/min

Inotropes increase cardiac contractility. Vasopressors cause vasoconstriction, increasing systemic vascular resistance. Some medications fit into both categories. Start at the low end of the range and titrate rapidly until shock reversal is achieved. If administering via peripheral an intravenous line, dilute the solution (usually 10× the usual central concentration). Additional "driver" fluid (3–5 mL/h of saline) may be needed if the infusion rate is very low (<1 mL/h).

Vasoactive Medications continued

- Warm shock is seen much less commonly in children, norepi is recommended as first-line.
- Dopamine second-line.

Intubation

- May be indicated for hemodynamic instability alone.
- Reduced work of breathing after intubation can reduce this oxygen consumption and divert critical cardiac output to vital organs.
- Fluid resuscitate and start vasopressors if necessary before intubation if possible because initiation of positive-pressure ventilation will decrease venous return and exacerbate hypotension.
- In a child with decreased cardiac function, the increased intrathoracic pressure associated with mechanical ventilation will afterload reduce the left ventricle and improve cardiac output
- Avoid Etomidate for septic shock, Ketamine is recommended.
- For shock without sepsis either medication is reasonable.

Antibiotics

- Broad-spectrum antibiotics within the first hour when sepsis is suspected.

Steroids

- Consider adjunctive stress-dose steroids if shock persists despite vasopressors- data in children does not show definite benefit.
- Hydrocortisone 2-4mg/kg/d

RESUSCITATION ENDPOINTS

The Surviving Sepsis Campaign identifies these therapeutic endpoints for resuscitation of pediatric shock: restoration of a CRT of less than 2 seconds, normal blood pressure for age, normal pulses, warm extremities, normal urine output, and normal mental status.

Goal-Directed Therapy

- ACCM recommends transfusion to a HgB>10g/dL and administration of maintenance fluids containing D10NS or D101/2NS.
- Lactate clearance, however, was notably excluded from the pediatric guidelines as a resuscitation endpoint based on the observation that many children in shock have normal lactate levels as well as the fact that lactate may be increased for many reasons other than cellular hypoxia.
- Resuscitation to specific EGDT goals may eventually go by the wayside in pediatric algorithms, but for now the ACCM continues to advocate for the titration of therapies to SVO2, perfusion pressure, and cardiac index goals.
- the Surviving Sepsis Campaign and ACCM recommend that resuscitation of children in septic shock should target a mixed venous saturation (SvO2) of 70% or greater, a perfusion pressure (mean arte-rial pressure – central venous pressure) of 55 1 1.5 ——————————— age in years, and cardiac index between 3.3 and 6.0 L/min/m2.