Chapter 6

Hemodynamics and Shock

Caregivers must have a basic understanding of pediatric vital signs to accurately perform hemodynamic monitoring and assess for shock (see Chapter 2, Anesthesia, Table 2-2). Cardiac output can be assessed by observing heart rate (HR) and capillary refill time, mental status changes, and urine output. Falling blood pressure (BP) is a late ominous sign. Preload can be assessed by observing changes in liver span or by viewing heart size with a chest radiograph. Systemic vascular resistance can be assessed by capillary refill time, pulse pressure, and differential temperatures peripheral to central (Table 6-1).

Table 6-1. Distinguishing Features of Clinical Shock States

	Physical				Monitoring		
Scenario	**WOB**	**CRT**	**Liver**	**Skin**	**CVP***	**SVR**	**CI**
Hypovolemic	nl	> 2	nl	Cool	↓	↑	↓
Cardiogenic	+++	> 2	+++	Cool	↑	↑	↓
Distributive	+/++	+/–	nl	+/–	↓	↓↑	↓↑

*Normal CVP for infants and children is 5–8 mmHg.
CI: cardiac index
CRT: capillary refill time
CVP: central venous pressure
nl: normal
SVR: systemic vascular resistance
WOB: work of breathing

Recognizing Shock

- Patient's history may include trauma, infection, heart murmur, or congenital heart disease
- Patient may exhibit poor perfusion manifested by capillary refill taking more than 3 seconds on the extremities or more than 2 seconds on the trunk
- Other signs and symptoms include tachycardia, hypotension (late finding), decreased peripheral pulses, decreased level of

consciousness, and decreased urinary output (normal goal ≥ 1 cc/kg/h), and may be associated with metabolic acidosis, tachypnea, and respiratory failure

- **Hypotension** is defined as a systolic BP of:
  - Infants 0–1 month old: < 60 mmHg
  - Infants 1–12 months old: < 70 mmHg
  - Children 1–10 years old: < 70 mmHg + 2(age [in years])

Types of Shock

- **Hypovolemic** shock results from blood loss or loss of other body fluids (Table 6-2)

Table 6-2. Assessing the Severity of Hypovolemic Shock*

Level	Weight Lost (infant)	Weight Lost (child)	Signs and Symptoms
Mild	5%	3%	Decreased urinary output, mild tachycardia, dry mucous membranes, decreased tearing
Moderate	10%	6%	Oliguria, tachycardia, dry membranes and tongue, sunken eyes and fontanelle, poor skin turgor, borderline to poor perfusion, mild to moderate tachypnea
Severe	15%	9%	Oliguria or anuria, possible shock, poor perfusion, decreased LOC, tachypnea, marked metabolic acidosis

*Percentages indicate actual weight loss from water loss or deficit.
LOC: level of consciousness

- **Cardiogenic** shock may be secondary to congenital heart disease
- **Distributive** shock includes septic shock and anaphylactic shock
- Other conditions that can cause shock include gastroenteritis, burns, trauma, hemorrhage, prolonged illness associated with poor oral intake, bowel obstruction, pneumonia, diabetic ketoacidosis, diabetes insipidus, neglect, cystic fibrosis, and inborn errors of metabolism

Treatment

- Stabilize airway, breathing, and circulation (ABCs); early mechanical ventilation may be indicated, particularly in septic shock
- Establish intravenous (IV) access (ideally in two locations)
- Administer rapid volume expansion with normal saline (NS) or Ringer's lactate bolus of 20 cc/kg in < 5–10 minutes, then reassess
    - Reassessment includes evaluating clinical appearance, chest auscultation, capillary refill, HR, BP, and, when possible, chest radiograph
    - If there is no improvement, repeat bolus as indicated by assessment; as intravascular volume is restored, the liver will expand and be palpable below the right costal margin
- Once perfusion has been normalized, continue to treat **hypovolemic** shock by calculating replacement fluids based on the estimated deficit (percent dehydration, see Table 6-2), ongoing losses, maintenance needs, and special situations (eg, hypernatremia or hyponatremia)
- Deficit replacement can be calculated using the following formula:

  $$\% \text{ deficit} \times \text{weight (grams)} = \text{fluid deficit in cc}$$

  For example, 10% dehydration of a 7-kg infant would be calculated as follows:

  $$10\% \times 7{,}000 \text{ g} = 700 \text{ g or } 700 \text{ cc}$$

  Add deficit to maintenance fluids of 700 cc to give 1,400 cc for the day
- Resuscitation of septic shock must be aggressive and timely
    - Signs of sepsis may be subtle but can include tachycardia, tachypnea for age along with high or low white blood cell count, fever, and hypothermia
    - Diagnosis: perfusional abnormalities accompanying suspected infection, and hypotension refractory to fluid resuscitation
    - Begin management by assessing ABCs and providing fluid resuscitation with isotonic crystalloid

Table 6-3. Vasoactive Support

Drug/Indication	Dosing	Effects	Action	Comments
Dopamine Septic shock Cardiogenic shock	Start at 5 μg/kg/min; range 2–20 μg/kg/min	β 5–10 μg/kg/min α > 15 μg/kg/min	Acts indirectly via NE release; inotrope, chronotrope, vasopressor	Give centrally if possible; not as effective in neonates who have limited NE stores
Dobutamine Cardiogenic shock	Start at 5 μg/kg/min; range 2–20 μg/kg/min	β	Direct-acting pure inotrope, lusitrope (diastolic relaxation)	May result in peripheral vasorelaxation and tachycardia
Epinephrine Postarrest shock Cold "septic" shock after dopamine	Start at 0.1 μg/kg/min; range 0.05–1.0 μg/kg/min	β at low doses α at higher doses	Direct-acting inotrope, chronotrope, and potent vasopressor	Give centrally if possible; may cause organ ischemia at high doses
Norepinephrine Warm septic shock refractory to dopamine	0.05–? μg/kg/min	α:β 3:1	Direct-acting potent vasopressor	Give centrally if possible; may cause organ ischemia
Phenylephrine Spinal shock Septic shock	0.05–? μg/kg/min	Pure α	Direct-acting potent vasopressor	Give centrally (burns)
Milrinone ↑ PVR or SVR with cardiac dysfunction	0.2–1 μg/kg/min; load 50 μg/kg	Phosphodiesterase inhibition (↑ cAMP)	Inotrope and vasodilator, lusitrope (diastolic relaxation)	Thrombocytopenia, T ½ h vs min
Nitroprusside Hypertension or ↑ SVR states	0.5–5 μg/kg/min	Exogenous NO donor	Potent arteriolar vasodilator	Need A-line to watch BP; cyanide toxicity

BP: blood pressure cAMP: cyclic adenosine monophosphate NE: norepinephrine NO: nitric oxide PVR: pulmonary vascular resistance

    - Pediatric patients in septic shock may need more than 60 mL/kg in the first hour
    - Consider transfusing packed red blood cells to reach goal hemoglobin of 10 g/dL
- Add vasoactive support in the first hour if fluid resuscitation fails to reverse septic shock (Table 6-3)
    - Initiate dopamine or epinephrine first
    - 80% of children will need inotrope before vasopressor
    - If shock persists despite fluids and dopamine is titrated up to 10 μg/kg/min:
        - Add epinephrine for cold shock (myocardial depression, leaky capillaries, metabolic acidosis, cool and mottled extremities)

          OR
        - Add norepinephrine for warm shock (increased carbon monoxide, bounding pulses, decreased systemic vascular resistance, warm extremities, normal or extremely fast capillary refill time, wide pulse pressures)
- Correct metabolic and electrolyte disturbances
    - Check and correct glucose and calcium levels
- When sepsis is suspected, administer broad-spectrum antibiotics within an hour
- Therapeutic goals include:
    - Normalized mental status
    - Central pulses equal to peripheral pulses
    - Urinary output > 1 mL/kg/h
    - Mean arterial pressure minus central venous pressure (if available):
        - > 60 mmHg in infants
        - > 65 mmHg for older children
    - Central venous oxygen saturation > 70% (if available)