Shock is an acute process characterized by the body's inability to deliver adequate oxygen to meet the metabolic demands of vital organs and tissues.

Table 88.1 Types of Shock

HYPOVOLEMIC	CARDIOGENIC	DISTRIBUTIVE	SEPTIC	OBSTRUCTIVE
Decreased preload secondary to internal or external losses	Cardiac pump failure secondary to poor myocardial function	Abnormalities of vasomotor tone from loss of venous and arterial capacitance	Encompasses multiple forms of shock Hypovolemic: third spacing of fluids into the extracellular, interstitial space Distributive: early shock with decreased afterload Cardiogenic: depression of myocardial function by endotoxins	Decreased cardiac output secondary to direct impediment to right- or left-sided heart outflow or restriction of all cardiac chambers
POTENTIAL ETIOLOGIES				
Blood loss: hemorrhage Plasma loss: burns, nephrotic syndrome Water/electrolyte loss: vomiting, diarrhea	Congenital heart disease Cardiomyopathies: infectious or acquired, dilated or restrictive Ischemia Arrhythmias	Anaphylaxis Neurologic: loss of sympathetic vascular tone secondary to spinal cord or brainstem injury Drugs	Bacterial Viral Fungal (immunocompromised patients are at increased risk)	Tension pneumothorax Pericardial tamponade Pulmonary embolism Anterior mediastinal masses Critical coarctation of aorta

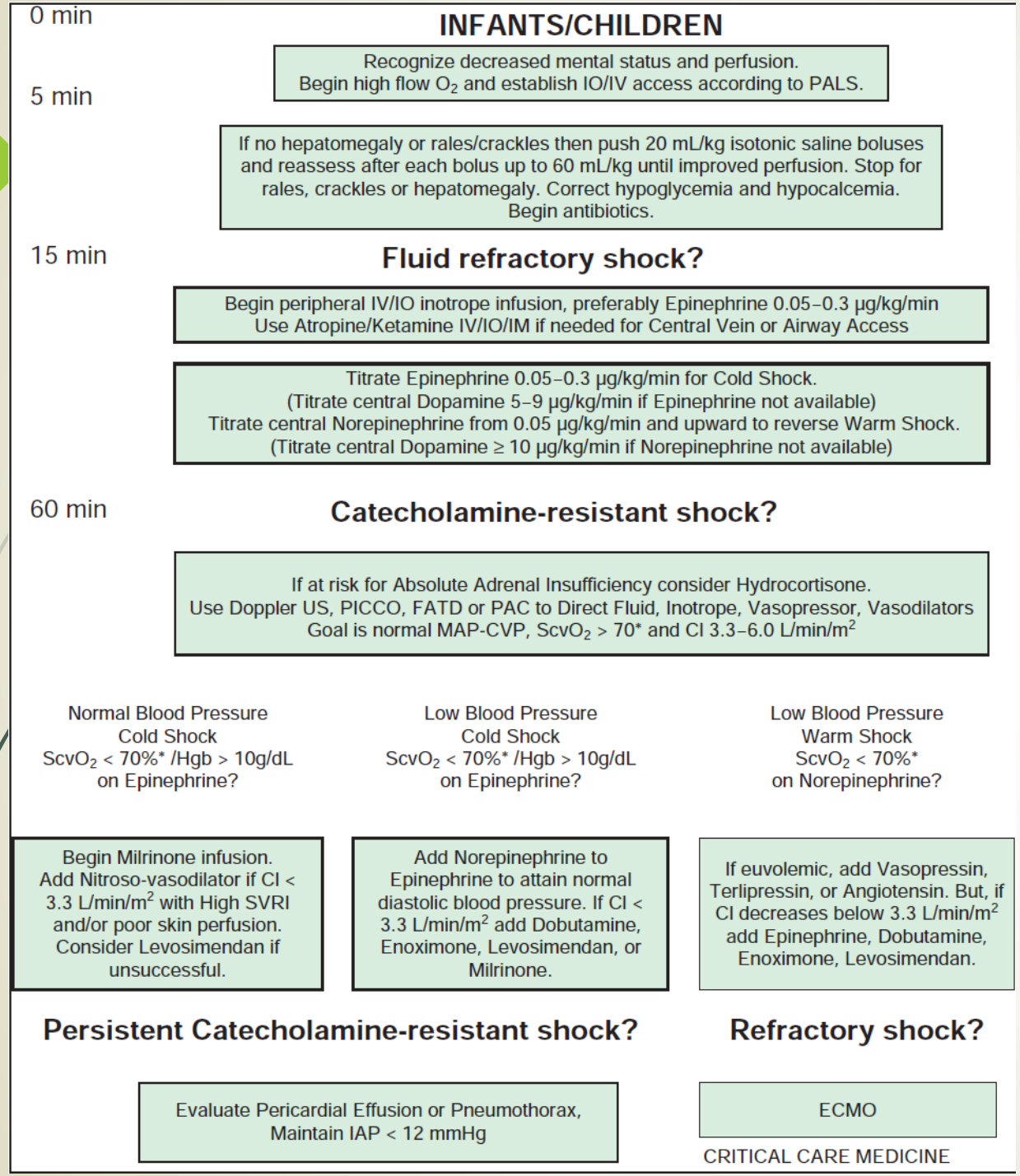

Fig. 88.2 American College of Critical Care Medicine algorithm for time-sensitive, goal-directed stepwise management of hemodynamic support in *infants and children*. Proceed to next step if shock persists. (1) First-hour goals—restore and maintain heart rate thresholds, capillary refill ≤ 2 sec, and normal blood pressure in the 1st hr/emergency department. (2) Subsequent ICU goals—if shock not reversed, proceed to restore and maintain normal perfusion pressure (MAP – CVP) for age, $ScvO_2$ > 70% (*except congenital heart patients with mixing lesions), and cardiac index > 3.3 and < 6.0 L/min/m^2 in PICU. *(From Davis AL, Carcillo JA, Aneja RK, et al: American College of Critical Care Medicine clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock,* Crit Care Med *45:1061–1093,*

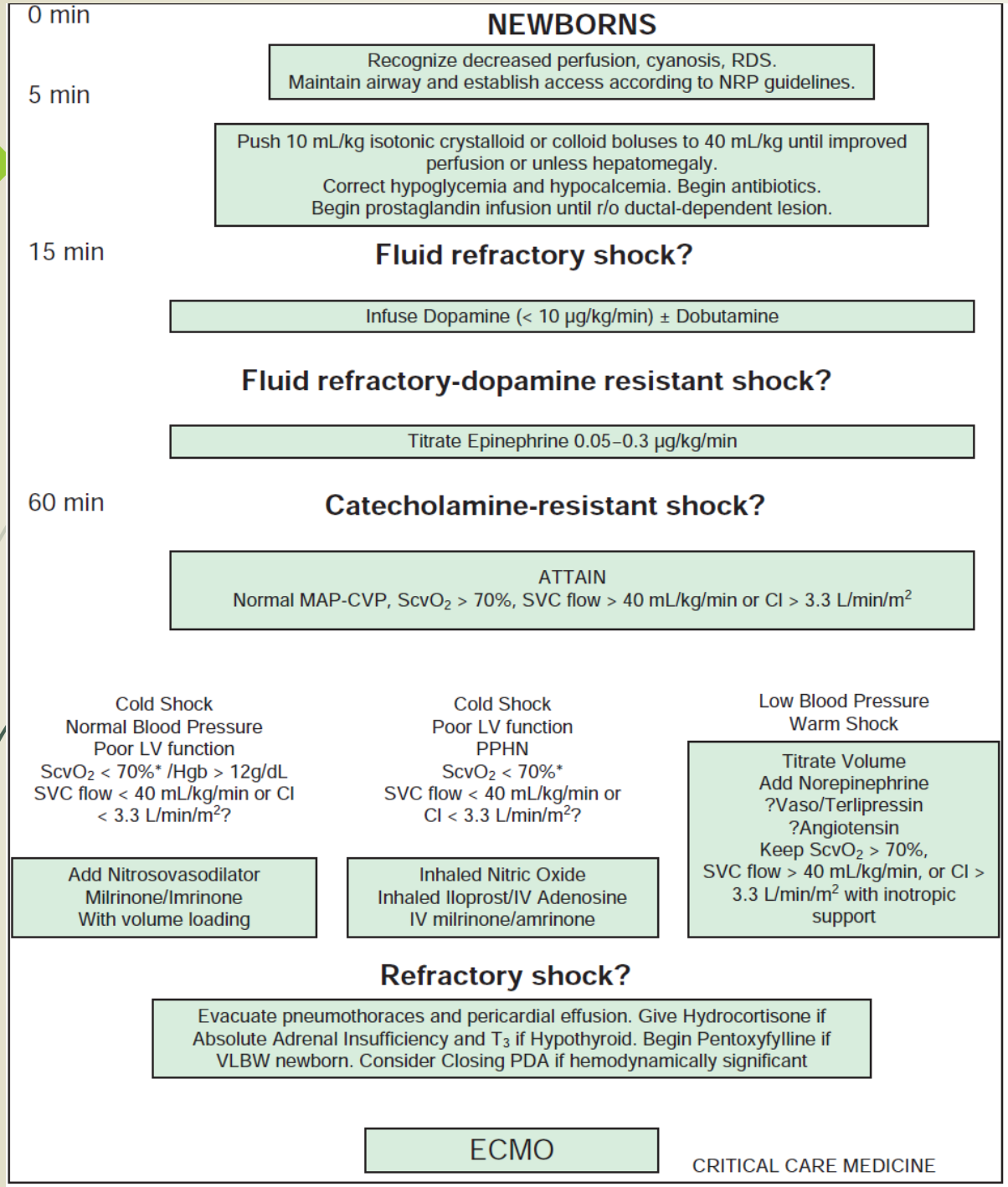

Fig. 88.1 American College of Critical Care Medicine algorithm for time-sensitive, goal-directed stepwise management of hemodynamic support in *newborns*. Proceed to next step if shock persists. (1) First-hour goals—restore and maintain heart rate thresholds, capillary refill ≤ 2 sec, and normal blood pressure in the 1st hr. (2) Subsequent ICU goals—restore normal perfusion pressure (mean arterial pressure – central venous pressure), preductal and postductal oxygen saturation difference < 5%, and either $ScvO_2$ > 70% (*except congenital heart patients with mixing lesions), superior vena cava flow > 40 mL/kg/min, or cardiac index > 3.3 L/min/m^2 in NICU. *(From Davis AL, Carcillo JA, Aneja RK, et al: American College of Critical Care Medicine clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock,* Crit Care Med *45:1061–1093, 2017, Fig 4.)*

Table 88.2	Criteria for Organ Dysfunction
ORGAN SYSTEM	**CRITERIA FOR DYSFUNCTION**
Cardiovascular	Despite administration of isotonic intravenous fluid bolus ≥60 mL/kg in 1 hr: decrease in BP (hypotension) systolic BP <90 mm Hg, mean arterial pressure <70 mm Hg, <5th percentile for age, or systolic BP <2 SD below normal for age *or* Need for vasoactive drug to maintain BP in normal range (dopamine >5 µg/kg/min or dobutamine, epinephrine, or norepinephrine at any dose) *or* Two of the following: Unexplained metabolic acidosis: base deficit >5.0 mEq/L Increased arterial lactate: >1 mmol/L or >2× upper limit of normal Oliguria: urine output <0.5 mL/kg/hr Prolonged capillary refill: >5 sec Core-to-peripheral temperature gap: >3°C (5.4°F)
Respiratory	PaO_2/FIO_2 ratio <300 in absence of cyanotic heart disease or preexisting lung disease *or* $PaCO_2$ >65 torr or 20 mm Hg over baseline $PaCO_2$ *or* Need for >50% FIO_2 to maintain saturation ≥92% *or* Need for nonelective invasive or noninvasive mechanical ventilation
Neurologic	GCS score ≤11 *or* Acute change in mental status with decrease in GCS score ≥3 points from abnormal baseline
Hematologic	Platelet count <100,000/mm^3 or decline of 50% in platelet count from highest value recorded over last 3 days (for patients with chronic hematologic or oncologic disorders) *or* INR >1.5 *or* Activated prothrombin time >60 sec
Renal	Serum creatinine >0.5 mg/dL, ≥2× upper limit of normal for age, or 2-fold increase in baseline creatinine value
Hepatic	Total bilirubin ≥4 mg/dL (not applicable for newborn) Alanine transaminase level 2× upper limit of normal for age

BP, Blood pressure; FIO_2, fraction of inspired oxygen; GCS, Glasgow Coma Scale; INR, international normalized ratio; $PaCO_2$, arterial partial pressure of carbon dioxide; PaO_2, partial pressure arterial oxygen; SD, standard deviations.

Table 88.3 Signs of Decreased Perfusion

ORGAN SYSTEM	↓ PERFUSION	↓↓ PERFUSION	↓↓↓ PERFUSION
Central nervous system	—	Restless, apathetic, anxious	Agitated/confused, stuporous, coma
Respiration	—	↑ Ventilation	↑↑ Ventilation
Metabolism	—	Compensated metabolic acidemia	Uncompensated metabolic acidemia
Gut	—	↓ Motility	Ileus
Kidney	↓ Urine volume ↑ Urinary specific gravity	Oliguria (<0.5 mL/kg/hr)	Oliguria/anuria
Skin	Delayed capillary refill	Cool extremities	Mottled, cyanotic, cold extremities
Cardiovascular system	↑ Heart rate	↑↑ Heart rate ↓ Peripheral pulses	↑↑ Heart rate ↓ Blood pressure, central pulses only

Table 88.6 Hemodynamic Variables in Different Shock States

TYPE OF SHOCK	CARDIAC OUTPUT	SYSTEMIC VASCULAR RESISTANCE	MEAN ARTERIAL PRESSURE	CAPILLARY WEDGE PRESSURE	CENTRAL VENOUS PRESSURE
Hypovolemic	↓	↑	↔ or ↓	↓↓↓	↓↓↓
Cardiogenic*					
Systolic	↓↓	↑↑↑	↔ or ↓	↑↑	↑↑
Diastolic	↔	↑↑	↔	↑↑	↑
Obstructive	↓	↑	↔ or ↓	↑↑†	↑↑†
Distributive	↑↑	↓↓↓	↔ or ↓	↔ or ↓	↔ or ↓
Septic					
Early	↑↑↑	↓↓↓	↔ or ↓‡	↓	↓
Late	↓↓	↓↓	↓↓	↑	↑ or ↔

*Systolic or diastolic dysfunction.
†Wedge pressure, central venous pressure, and pulmonary artery diastolic pressures are equal.
‡Wide pulse pressure.

Table 88.4 Pathophysiology of Shock

Extracorporeal Fluid Loss

Hypovolemic shock may be a result of direct blood loss through hemorrhage or abnormal loss of body fluids (diarrhea, vomiting, burns, diabetes mellitus or insipidus, nephrosis).

Lowering Plasma Oncotic Forces

Hypovolemic shock may also result from hypoproteinemia (liver injury, or as a progressive complication of increased capillary permeability).

Abnormal Vasodilation

Distributive shock (neurogenic, anaphylaxis, or septic shock) occurs when there is loss of vascular tone—venous, arterial, or both (sympathetic blockade, local substances affecting permeability, acidosis, drug effects, spinal cord transection).

Increased Vascular Permeability

Sepsis may change the capillary permeability in the absence of any change in capillary hydrostatic pressure (endotoxins from sepsis, excess histamine release in anaphylaxis).

Cardiac Dysfunction

Peripheral hypoperfusion may result from any condition that affects the heart's ability to pump blood efficiently (ischemia, acidosis, drugs, constrictive pericarditis, pancreatitis, sepsis).

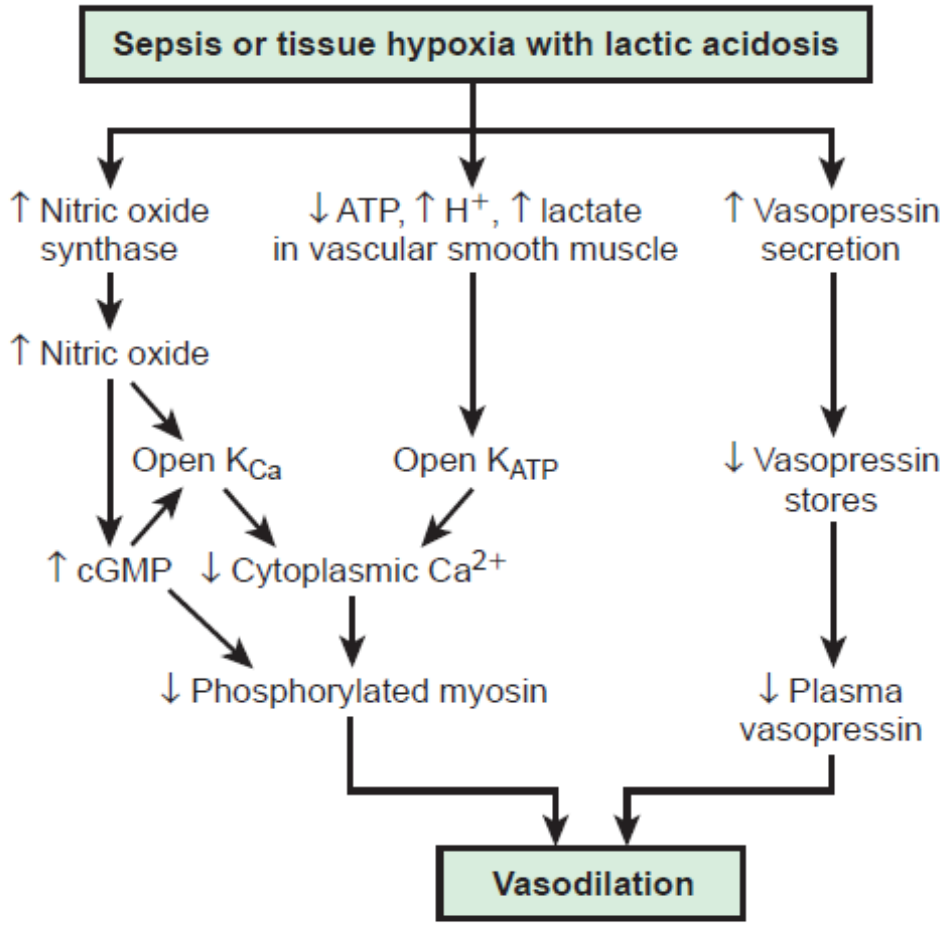

Fig. 88.3 Mechanisms of vasodilatory shock. Septic shock and states of prolonged shock causing tissue hypoxia with lactic acidosis increase nitric oxide synthesis, activate the adenosine triphosphate (ATP)–sensitive and calcium-regulated potassium channels (K_{ATP} and K_{Ca}, respectively) in vascular smooth muscle, and lead to depletion of vasopressin. cGMP, Cyclic guanosine monophosphate. *(From Landry DW, Oliver JA: The pathogenesis of vasodilatory shock,* N Engl J Med *345:588.595, 2001.)*

Table 88.5 Differential Diagnosis of Systemic Inflammatory Response Syndrome (SIRS)

INFECTION
Bacteremia or meningitis (*Streptococcus pneumoniae, Haemophilus influenzae* type b, *Neisseria meningitidis*, group A streptococcus, *Staphylococcus aureus*)
Viral illness (influenza, enteroviruses, hemorrhagic fever group, herpes simplex virus, respiratory syncytial virus, cytomegalovirus, Epstein-Barr virus)
Encephalitis (arboviruses, enteroviruses, herpes simplex virus)
Rickettsiae (Rocky Mountain spotted fever, *Ehrlichia*, Q fever)
Syphilis
Vaccine reaction (pertussis, influenza, measles)
Toxin-mediated reaction (toxic shock, staphylococcal scalded skin syndrome)

CARDIOPULMONARY
Pneumonia (bacteria, virus, mycobacteria, fungi, allergic reaction)
Pulmonary emboli
Heart failure
Arrhythmia
Pericarditis
Myocarditis

METABOLIC-ENDOCRINE
Adrenal insufficiency (adrenogenital syndrome, Addison disease, corticosteroid withdrawal)
Electrolyte disturbances (hypo- or hypernatremia; hypo- or hypercalcemia)
Diabetes insipidus
Diabetes mellitus
Inborn errors of metabolism (organic acidosis, urea cycle, carnitine deficiency, mitochondrial disorders)
Hypoglycemia
Reye syndrome

GASTROINTESTINAL
Gastroenteritis with dehydration
Volvulus
Intussusception
Appendicitis
Peritonitis (spontaneous, associated with perforation or peritoneal dialysis)
Necrotizing enterocolitis
Hepatitis
Hemorrhage
Pancreatitis

HEMATOLOGIC
Anemia (sickle cell disease, blood loss, nutritional)
Methemoglobinemia
Splenic sequestration crisis
Leukemia or lymphoma
Hemophagocytic syndromes

NEUROLOGIC
Intoxication (drugs, carbon monoxide, intentional or accidental overdose)
Intracranial hemorrhage
Infant botulism
Trauma (child abuse, accidental)
Guillain-Barré syndrome
Myasthenia gravis

OTHER
Anaphylaxis (food, drug, insect sting)
Hemolytic-uremic syndrome
Kawasaki disease
Erythema multiforme
Hemorrhagic shock–encephalopathy syndrome
Poisoning
Toxic envenomation
Macrophage activation syndrome
Idiopathic systemic capillary leak (Clarkson) syndrome

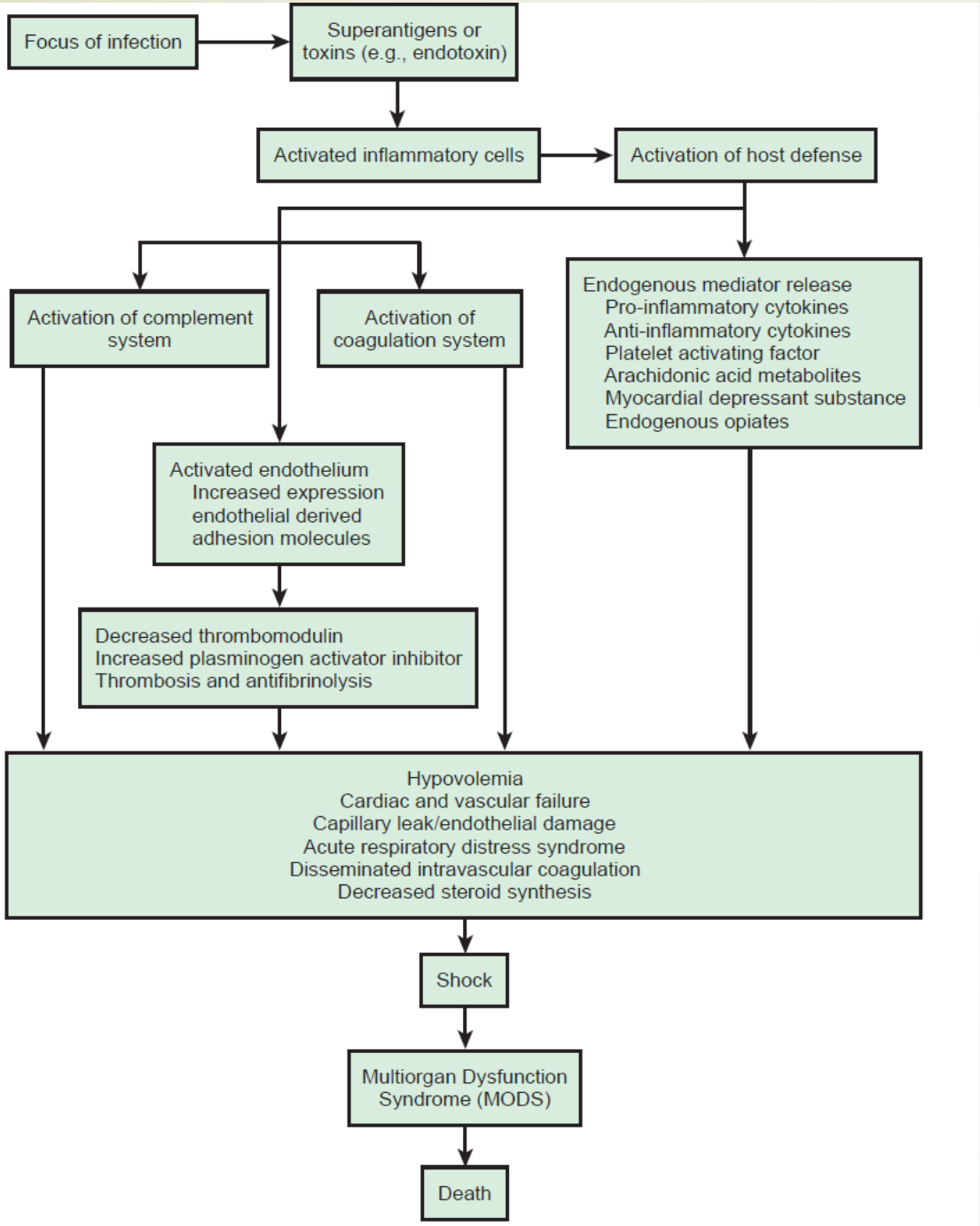

Fig. 88.4 Hypothetical pathophysiology of the septic process.

Table 88.7 International Consensus Definitions for Pediatric Sepsis

Infection

Suspected or proven infection or a clinical syndrome associated with high probability of infection.

Systemic Inflammatory Response Syndrome (SIRS)

Two of 4 criteria, 1 of which must be abnormal temperature or abnormal leukocyte count:

1. Core temperature >38.5°C (101.3°F) or <36°C (96.8°F) (rectal, bladder, oral, or central catheter)
2. Tachycardia:
   Mean heart rate >2 SD above normal for age in absence of external stimuli, chronic drugs or painful stimuli
   or
   Unexplained persistent elevation over 0.5-4 hr
   or
   In children <1 yr old, persistent bradycardia over 0.5 hr (mean heart rate <10th percentile for age in absence of vagal stimuli, β-blocker drugs, or congenital heart disease)
3. Respiratory rate >2 SD above normal for age or acute need for mechanical ventilation not related to neuromuscular disease or general anesthesia
4. Leukocyte count elevated or depressed for age (not secondary to chemotherapy) or >10% immature neutrophils

Sepsis

SIRS plus a suspected or proven infection

Severe Sepsis

Sepsis plus 1 of the following:

1. Cardiovascular organ dysfunction, defined as:
   Despite >40 mL/kg of isotonic intravenous fluid in 1 hr:
   - Hypotension <5th percentile for age or systolic blood pressure <2 SD below normal for age

   or
   - Need for vasoactive drug to maintain blood pressure

   or
   Two of the following:
   - Unexplained metabolic acidosis: base deficit >5 mEq/L
   - Increased arterial lactate: >2 times upper limit of normal
   - Oliguria: urine output <0.5 mL/kg/hr
   - Prolonged capillary refill: >5 sec
   - Core-to-peripheral temperature gap: >3°C (5.4°F)
2. Acute respiratory distress syndrome (ARDS), as defined by the presence of a PaO_2/FIO_2 ratio ≤300 mm Hg, bilateral infiltrates on chest radiograph, and no evidence of left-sided heart failure.
   or
   Sepsis plus ≥2 organ dysfunctions (respiratory, renal, neurologic, hematologic, or hepatic).

Septic Shock

Sepsis plus cardiovascular organ dysfunction as defined above.

Multiple-Organ Dysfunction Syndrome (MODS)

Presence of altered organ function such that homeostasis cannot be maintained without medical intervention.

FIO_2, Fraction of inspired oxygen; PaO_2, partial pressure of arterial oxygen; SD, standard deviations.

Table 88.8 Goal-Directed Therapy of Organ System Dysfunction in Shock

SYSTEM	DISORDERS	GOALS	THERAPIES
Respiratory	Acute respiratory distress syndrome Respiratory muscle fatigue Central apnea	Prevent/treat: hypoxia and respiratory acidosis Prevent barotrauma Decrease work of breathing	Oxygen Noninvasive ventilation Early endotracheal intubation and mechanical ventilation Positive end-expiratory pressure (PEEP) Permissive hypercapnia High-frequency ventilation Extracorporeal membrane oxygenation (ECMO)
Renal	Prerenal failure Renal failure	Prevent/treat: hypovolemia, hypervolemia, hyperkalemia, metabolic acidosis, hypernatremia/hyponatremia, and hypertension Monitor serum electrolytes	Judicious fluid resuscitation Establishment of normal urine output and blood pressure for age Furosemide (Lasix) Dialysis, ultrafiltration, hemofiltration
Hematologic	Coagulopathy (disseminated intravascular coagulation) Thrombosis	Prevent/treat: bleeding Prevent/treat: abnormal clotting	Vitamin K Fresh-frozen plasma Platelets Heparinization
Gastrointestinal	Stress ulcers Ileus Bacterial translocation	Prevent/treat: gastric bleeding Avoid aspiration, abdominal distention Avoid mucosal atrophy	Histamine H_2-receptor–blocking agents or proton pump inhibitors Nasogastric tube Early enteral feedings
Endocrine	Adrenal insufficiency, primary or secondary to chronic steroid therapy	Prevent/treat: adrenal crisis	Stress-dose steroids in patients previously given steroids Physiologic dose for presumed primary insufficiency in sepsis
Metabolic	Metabolic acidosis	Correct etiology Normalize pH	Treatment of hypovolemia (fluids), poor cardiac function (fluids, inotropic agents) Improvement of renal acid excretion Low-dose (0.5-2.0 mEq/kg) sodium bicarbonate if patient is not showing response, pH <7.1, and ventilation (CO_2 elimination) is adequate

Table 88.9 Recommendations for Shock: Initial Resuscitation and Infection Issues—Adults

INITIAL RESUSCITATION

1. Protocolized, quantitative resuscitation of patients with sepsis-induced tissue hypoperfusion (defined as hypotension persisting after initial fluid challenge or blood lactate concentration ≥4 mmol/L). Goals during the 1st 6 hr of resuscitation:
   a. Central venous pressure 8-12 mm Hg
   b. Mean arterial pressure (MAP) ≥65 mm Hg
   c. Urine output ≥0.5 mL kg^{-1} hr
   d. Central venous (superior vena cava) or mixed venous oxygen saturation: 70% or 65%, respectively
2. In patients with elevated lactate levels, targeting resuscitation to normalize lactate as rapidly as possible.

SCREENING FOR SEPSIS AND PERFORMANCE IMPROVEMENT

1. Routine screening of potentially infected seriously ill patients for severe sepsis to allow earlier implementation of therapy.
2. Hospital-based performance improvement efforts in severe sepsis.

DIAGNOSIS

1. Cultures as clinically appropriate before antimicrobial therapy if no significant delay (>45 min) in the start of antimicrobial(s). At least 2 sets of blood cultures (both aerobic and anaerobic bottles) should be obtained before antimicrobial therapy with at least 1 drawn percutaneously and 1 drawn through each vascular access device, unless the device was recently (<48 hr) inserted.
2. Use of the 1,3 β-D-glucan assay, mannan and antimannan antibody assays, if available, and invasive candidiasis is in differential diagnosis of cause of infection.
3. Imaging studies performed promptly to confirm a potential source of infection.

ANTIMICROBIAL THERAPY

1. Administration of effective intravenous antimicrobials within the 1st hr of recognition of septic shock and severe sepsis without septic shock as the goal of therapy.

2a. Initial empirical antiinfective therapy of 1 or more drugs that have activity against all likely pathogens (bacterial and/or fungal or viral) and that penetrate in adequate concentrations into tissues presumed to be the source of sepsis.

2b. Antimicrobial regimen should be reassessed daily for potential deescalation.

3. Use of low procalcitonin levels or similar biomarkers to assist the clinician in the discontinuation of empirical antibiotics in patients who initially appeared septic, but have no subsequent evidence of infection.

4a. Combination empirical therapy for neutropenic patients with severe sepsis and for patients with difficult-to-treat, multidrug-resistant bacterial pathogens such as *Acinetobacter* and *Pseudomonas* spp.
For patients with severe infections associated with respiratory failure and septic shock, combination therapy with an extended-spectrum β-lactam and either an aminoglycoside or a fluoroquinolone is for *Pseudomonas aeruginosa* bacteremia. A combination of β-lactam and macrolide for patients with septic shock from bacteremic *Streptococcus pneumoniae* infections.

4b. Empirical combination therapy should not be administered for more than 3-5 days. Deescalation to the most appropriate single therapy should be performed as soon as the susceptibility profile is known.

5. Duration of therapy typically 7-10 days; longer courses may be appropriate in patients who have a slow clinical response,

Table 88.9 Recommendations for Shock: Initial Resuscitation and Infection Issues—Adults—cont'd

undrainable foci of infection, bacteremia with *Staphylococcus aureus*, some fungal and viral infections, or immunodeficiencies (e.g., neutropenia).
6. Antiviral therapy initiated as early as possible in patients with severe sepsis or septic shock of viral origin.
7. Antimicrobial agents should *not* be used in patients with severe inflammatory states determined to be of noninfectious cause.

SOURCE CONTROL

1. A specific anatomic diagnosis of infection requiring consideration for emergent source control should be sought and diagnosed or excluded as rapidly as possible, and intervention undertaken for source control within the 1st 12 hr after the diagnosis is made, if feasible.
2. When infected peripancreatic necrosis is identified as a potential source of infection, definitive intervention is best delayed until adequate demarcation of viable and nonviable tissues has occurred.
3. When source control in a severely septic patient is required, the effective intervention associated with the least physiologic insult should be used (e.g., percutaneous rather than surgical drainage of an abscess).
4. If intravascular access devices are a possible source of severe sepsis or septic shock, these should be removed promptly after other vascular access has been established.

INFECTION PREVENTION

1a. Selective oral decontamination and selective digestive decontamination should be introduced and investigated as a method to reduce the incidence of ventilator-associated pneumonia; this infection control measure can then be instituted in healthcare settings and regions where this methodology is found to be effective.

1b. Oral chlorhexidine gluconate be used as a form of oropharyngeal decontamination to reduce the risk of ventilator-associated pneumonia in ICU patients with severe sepsis.

Adapted from Dellinger PR, Levy MM, Rhodes A, et al: Surviving sepsis campaign: International guidelines for management of severe sepsis and septic shock: 2012, *Crit Care Med* 41(2):580–637, 2013 (Table 5, p 589).

Table 88.10 Surviving Sepsis Campaign: Care Bundles

To be completed within 3 hr:
1. Measure lactate level.
2. Obtain blood cultures before administration of antibiotics.
3. Administer broad-spectrum antibiotics.
4. Administer 30 mL/kg crystalloid for hypotension or lactate ≥4 mmol/L.

To completed within 6 hr:
5. Apply vasopressors (for hypotension that does not respond to initial fluid resuscitation) to maintain a mean arterial pressure (MAP) ≥65 mm Hg.
6. In the event of persistent arterial hypotension despite volume resuscitation (septic shock) or initial lactate ≥4 mmol/L (36 mg/dL): Measure central venous pressure (CVP).* Measure central venous oxygen saturation ($ScvO_2$).*
7. Remeasure lactate if initial lactate was elevated.*

*Targets for quantitative resuscitation included in the guidelines are CVP of ≥8 mm Hg, $ScvO_2$ of ≥70%, and normalization of lactate.
Adapted from Dellinger PR, Levy MM, Rhodes A, et al: Surviving Sepsis campaign: international guidelines for management of severe sepsis and septic shock: 2012. *Crit Care Med* 41(2):580–637, 2013 (Fig 1, p 591).

Table 88.11 Recommendations for Shock: Hemodynamic Support and Adjunctive Therapy—Adults

FLUID THERAPY OF SEVERE SEPSIS

1. Crystalloids as the initial fluid of choice in the resuscitation of severe sepsis and septic shock.
2. Against the use of hydroxyethyl starches for fluid resuscitation of severe sepsis and septic shock.
3. Albumin in the fluid resuscitation of severe sepsis and septic shock when patients require substantial amounts of crystalloids.
4. Initial fluid challenge in patients with sepsis-induced tissue hypoperfusion with suspicion of hypovolemia, to achieve a minimum of 30 mL/kg of crystalloids (a portion of this may be albumin equivalent). More rapid administration and greater amounts of fluid may be needed in some patients.
5. Fluid challenge technique be applied in which fluid administration is continued as long as there is hemodynamic improvement either based on dynamic (e.g., change in pulse pressure, stroke volume variation) or static (e.g., arterial pressure, heart rate) variables.

VASOPRESSORS

1. Vasopressor therapy initially to target a mean arterial pressure (MAP) of 65 mm Hg.
2. Norepinephrine as the first-choice vasopressor.
3. Epinephrine (added to and potentially substituted for norepinephrine) when an additional agent is needed to maintain adequate blood pressure.
4. Vasopressin 0.03 units/min can be added to norepinephrine (NE) with intent of either raising MAP or decreasing NE dosage.
5. Low-dose vasopressin is not recommended as the single initial vasopressor for treatment of sepsis-induced hypotension, and vasopressin doses >0.03-0.04 units/min should be reserved for salvage therapy (failure to achieve adequate MAP with other vasopressor agents).
6. Dopamine as an alternative vasopressor agent to NE only in highly selected patients (e.g., with low risk of tachyarrhythmias and absolute or relative bradycardia).
7. Phenylephrine is not recommended in the treatment of septic shock except in circumstances where (a) NE is associated with serious arrhythmias, (b) cardiac output is known to be high and blood pressure persistently low, or (c) as salvage therapy when combined inotrope/vasopressor drugs and low-dose vasopressin have failed to achieve MAP target.
8. Low-dose dopamine should not be used for renal protection.
9. All patients requiring vasopressors have an arterial catheter placed as soon as practical if resources are available.

INOTROPIC THERAPY

1. A trial of dobutamine infusion up to 20 μg/kg/min be administered or added to vasopressor (if in use) in the presence of (a) myocardial dysfunction as suggested by elevated cardiac filling pressures and low cardiac output, or (b) ongoing signs of hypoperfusion, despite achieving adequate intravascular volume and adequate MAP.
2. Not using a strategy to increase cardiac index to predetermined supranormal levels.

CORTICOSTEROIDS

1. Not using intravenous hydrocortisone to treat adult septic shock patients, if adequate fluid resuscitation and vasopressor therapy

Table 88.11 Recommendations for Shock: Hemodynamic Support and Adjunctive Therapy—Adults—cont'd

are able to restore hemodynamic stability (see goals for Initial Resuscitation). In the event this is not achievable, we suggest IV hydrocortisone alone at a dose of 200 mg/day.
2. Not using the ACTH stimulation test to identify adults with septic shock who should receive hydrocortisone.
3. In treated patients, hydrocortisone tapered when vasopressors are no longer required.
4. Corticosteroids should *not* be administered for the treatment of sepsis in the absence of shock.
5. When hydrocortisone is given, use continuous flow.

Adapted from Dellinger PR, Levy MM, Rhodes A, et al: Surviving Sepsis campaign: international guidelines for management of severe sepsis and septic shock: 2012, *Crit Care Med* 41(2):580–637, 2013 (Table 6, p 596).

Table 88.13 Cardiovascular Drug Treatment of Shock

DRUG	EFFECT(S)	DOSING RANGE	COMMENT(S)
Dopamine	↑ Cardiac contractility Significant peripheral vasoconstriction at >10 µg/kg/min	3-20 µg/kg/min	↑ Risk of arrhythmias at high doses
Epinephrine	↑ Heart rate and ↑ cardiac contractility Potent vasoconstrictor	0.05-3.0 µg/kg/min	May ↓ renal perfusion at high doses ↑ Myocardial O_2 consumption Risk of arrhythmia at high doses
Dobutamine	↑ Cardiac contractility Peripheral vasodilator	1-10 µg/kg/min	—
Norepinephrine	Potent vasoconstriction No significant effect on cardiac contractility	0.05-1.5 µg/kg/min	↑ Blood pressure secondary to ↑ systemic vascular resistance ↑ Left ventricular afterload
Phenylephrine	Potent vasoconstriction	0.5-2.0 µg/kg/min	Can cause sudden hypertension ↑ O_2 consumption

Table 88.14 Vasodilators/Afterload Reducers in Treatment of Shock

DRUG	EFFECT(S)	DOSING RANGE	COMMENT(S)
Nitroprusside	Vasodilator (mainly arterial)	0.5-4.0 µg/kg/min	Rapid effect Risk of cyanide toxicity with prolonged use (>96 hr)
Nitroglycerin	Vasodilator (mainly venous)	1-20 µg/kg/min	Rapid effect Risk of increased intracranial pressure
Prostaglandin E_1	Vasodilator Maintains an open ductus arteriosus in the newborn with ductal-dependent congenital heart disease	0.01-0.2 µg/kg/min	Can lead to hypotension Risk of apnea
Milrinone	Increased cardiac contractility Improves cardiac diastolic function Peripheral vasodilation	Load 50 µg/kg over 15 min 0.5-1.0 µg/kg/min	Phosphodiesterase inhibitor—slows cyclic adenosine monophosphate breakdown

Table 88.12 Recommendations for Shock: Special Considerations in Pediatric Patients

INITIAL RESUSCITATION

1. For respiratory distress and hypoxemia, start with face mask oxygen or, if needed and available, high-flow nasal cannula oxygen or nasopharyngeal CPAP (NP CPAP). For improved circulation, peripheral intravenous access or intraosseous access can be used for fluid resuscitation and inotrope infusion when a central line is not available. If mechanical ventilation is required, cardiovascular instability during intubation is less likely after appropriate cardiovascular resuscitation.
2. Initial therapeutic end-points of resuscitation of septic shock: capillary refill of ≤2 sec, normal blood pressure for age, normal pulses with no differential between peripheral and central pulses, warm extremities, urine output >1 mL kg^{-1} hr^{-1}, and normal mental status. $ScvO_2$ saturation ≥70% and cardiac index between 3.3 and 6.0 L/min/m^2 should be targeted thereafter.
3. Follow American College of Critical Care Medicine–Pediatric Advanced Life Support (ACCM-PALS) guidelines for the management of septic shock.
4. Evaluate for and reverse pneumothorax, pericardial tamponade, or endocrine emergencies in patients with refractory shock.

ANTIBIOTICS AND SOURCE CONTROL

1. Empirical antibiotics should be administered within 1 hr of the identification of severe sepsis. Blood cultures should be obtained before administering antibiotics when possible, but this should not delay administration of antibiotics. The empirical drug choice should be changed as epidemic and endemic ecologies dictate (e.g., H1N1, methicillin-resistant *Staphylococcus aureus* [MRSA], chloroquine-resistant malaria, penicillin-resistant pneumococci, recent ICU stay, neutropenia).
2. Clindamycin and antitoxin therapies for toxic shock syndromes with refractory hypotension.
3. Early and aggressive source control.
4. *Clostridium difficile* colitis should be treated with enteral antibiotics if tolerated. Oral vancomycin is preferred for severe disease.

FLUID RESUSCITATION

1. In the industrialized world with access to inotropes and mechanical ventilation, initial resuscitation of hypovolemic shock begins with infusion of isotonic crystalloids or albumin with boluses of up to 20 mL/kg crystalloids (or albumin equivalent) over 5-10 min, titrated to reversing hypotension, increasing urine output, and attaining normal capillary refill, peripheral pulses, and level of consciousness without inducing hepatomegaly or rales. If hepatomegaly or rales present, inotropic support should be implemented, not fluid resuscitation. In nonhypotensive children with severe hemolytic anemia (severe malaria or sickle cell crises), blood transfusion is considered superior to crystalloid or albumin bolus.

INOTROPES, VASOPRESSORS, AND VASODILATORS

1. Begin peripheral inotropic support until central venous access can be attained in children who are not responsive to fluid resuscitation.
2. Patients with low cardiac output and elevated systemic vascular resistance states with normal blood pressure should be given vasodilator therapies in addition to inotropes.

EXTRACORPOREAL MEMBRANE OXYGENATION

1. Consider ECMO for refractory pediatric septic shock and respiratory failure.

CORTICOSTEROIDS

1. Timely hydrocortisone therapy in children with fluid-refractory, catecholamine-resistant shock and suspected or proven absolute (classic) adrenal insufficiency.

PROTEIN C AND ACTIVATED PROTEIN CONCENTRATE

No recommendations (no longer available).

BLOOD PRODUCTS AND PLASMA THERAPIES

1. Similar hemoglobin targets in children as in adults. During resuscitation of low superior vena cava oxygen saturation shock (<70%), hemoglobin levels of 10 g/dL are targeted. After stabilization and recovery from shock and hypoxemia, a lower target (>7.0 g/dL) can be considered reasonable.
2. Similar platelet transfusion targets in children as in adults.
3. Use plasma therapies in children to correct sepsis-induced thrombotic purpura disorders, including progressive disseminated intravascular coagulation, secondary thrombotic microangiopathy, and thrombotic thrombocytopenic purpura.

MECHANICAL VENTILATION

1. Lung-protective strategies during mechanical ventilation.

SEDATION, ANALGESIA, AND DRUG TOXICITIES

1. We recommend use of sedation with a sedation goal in critically ill, mechanically ventilated patients with sepsis.
2. Monitor drug toxicity lab results because drug metabolism is reduced during severe sepsis, putting children at greater risk of adverse drug-related events.

GLYCEMIC CONTROL

1. Control hyperglycemia using a similar target as in adults (≤180 mg/dL). Glucose infusion should accompany insulin therapy in newborns and children because some hyperglycemic children make no insulin whereas others are insulin resistant.

DIURETICS AND RENAL REPLACEMENT THERAPY

1. Use diuretics to reverse fluid overload when shock has resolved, and if unsuccessful, use continuous venovenous hemofiltration (CVVH) or intermittent dialysis to prevent >10% total body weight fluid overload.

DEEP VEIN THROMBOSIS (DVT) PROPHYLAXIS

No recommendation on the use of DVT prophylaxis in prepubertal children with severe sepsis.

STRESS ULCER (SU) PROPHYLAXIS

No recommendation on the use of SU prophylaxis in prepubertal children with severe sepsis.

NUTRITION

1. Enteral nutrition given to children who can be fed enterally, and parenteral feeding in those who cannot (grade 2C).

CPAP, Continuous positive airway pressure.

Adapted from Dellinger PR, Levy MM, Rhodes A, et al: Surviving Sepsis campaign: International guidelines for management of severe sepsis and septic shock: 2012, *Crit Care Med* 41(2):580–637, 2013 (Table 9, p 614).