Chapter 9

Pharmacology

Overview

Introduction	This chapter contains information on drugs referenced in the *PALS Provider Manual.* A summary of indications and doses of the drugs outlined in this chapter may be found in the *PALS Course Guide* (Part 10: Pharmacology).
Drug Doses	The scientific basis for the pharmacologic treatment of seriously ill or injured infants and children is dynamic. Advances in management options and drug therapies occur rapidly. Readers are advised to check for changes in recommended doses, indications, and contraindications in the following sources: *Currents in Emergency Cardiovascular Care,* which is available at http://www.americanheart.org/cpr, the ECC Handbook, and the package insert product information sheet for each drug and medical device.
Note	This chapter contains selected pharmacology information. The focus of this information is the pharmacology of these agents when used for the treatment of seriously ill or injured children. The chapter contents should not be considered complete information on the pharmacology of these drugs.

Adenosine

Classification: Antiarrhythmic
Indications: SVT
Available Forms: Injection: 3 mg/mL
Dose and Administration:

SVT		
IV/IO	First dose	0.1 mg/kg IV/IO *rapid* push (maximum dose 6 mg)
	Second dose	0.2 mg/kg IV/IO *rapid* push (maximum dose 12 mg)

Actions:

- Stimulates adenosine receptors in heart and vascular smooth muscle
- Briefly blocks conduction through AV node
  - — Interrupts reentry pathways through AV node
  - — Allows return of normal sinus rhythm in patients with SVT, including SVT associated with Wolff-Parkinson-White (WPW) Syndrome
- Depresses sinus node automaticity

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	erythrocytes, vascular endothelium
Metabolism	erythrocytes, endothelium rapidly take up and metabolize adenosine
Excretion	urine
Half-life	≤10 seconds

Pharmacodynamics:

IV/IO

- Onset—rapid if given by rapid bolus
- Peak—unknown
- Duration—usually <1 minute

Monitoring: Monitor blood pressure frequently and ECG continuously.
Adverse Effects:

CNS	lightheadedness, dizziness, arm tingling, numbness, apprehension, blurred vision, headache
EENT	metallic taste, throat tightness
RESP	dyspnea, hyperventilation, bronchospasm
CV	hypotension, transient bradycardia or asystole, atrial tachyarrhythmias, angina, palpitations
GI	nausea
SKIN	facial flushing, sweating

Special Considerations:

- If possible record rhythm strip during administration.
- Administer via central venous access if present, otherwise by IV/IO site most proximal in extremity.
- Push adenosine rapidly IV/IO followed immediately by NS flush (5 to 10 mL).
- Theophylline is an adenosine receptor antagonist and reduces adenosine effectiveness.

Albumin

Classification: Blood product derivative (plasma volume expander)
Indications:

- Shock
- Trauma
- Burns

Available Forms: Injection: 5% (5 g/100 mL), 25% (25 g/100 mL)
Dose and Administration:

Shock, Trauma, Burns	
IV/IO	0.5 to 1 g/kg IV/IO by *rapid* infusion (10 to 20 mL/kg of 5% solution)

Actions:

- Expands intravascular volume through colloid oncotic effect. As a large molecule, albumin is more likely to remain in the intravascular space for a longer time than administered crystalloid. Oncotic effect may help expand the intravascular space by pulling water from the extravascular compartment.
- Supports preload and cardiac output.

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	initially to intravascular space, then throughout extracellular space at a rate affected by capillary permeability
Metabolism	liver
Excretion	unknown
Half-life	variable (affected by clinical setting); usually <24 hours

Pharmacodynamics:

IV/IO

- Onset—15 to 30 minutes
- Peak—unknown
- Duration—unknown

Monitoring: Monitor cardiorespiratory function and systemic perfusion.
Adverse effects:

RESP	pulmonary edema, increased respiratory rate, bronchospasm
CV	fluid overload, hypotension, tachycardia, hypertension (if fluid overload)
SKIN	rash, urticaria, flushing
MISC	fever

Precautions:

- Monitor for signs of pulmonary edema. Albumin binds calcium, so rapid infusions may decrease ionized calcium concentration, leading to hypotension.
- Albumin also binds many drugs, such as phenytoin, which may reduce free drug concentration and therapeutic effect. Albumin infusion may lead to increase in serum sodium concentration because it is prepared in NS.

Special Considerations:

- Blood product—transfusion-like reactions rarely occur.
- For IV administration, use within 4 hours of opening vial.
- The 5% albumin is generally used undiluted. The 25% albumin may be given undiluted or diluted in NS.

Albuterol

Classification: Bronchodilator, β_2-adrenergic agent

Indications:

- Asthma
- Anaphylaxis (bronchospasm)
- Hyperkalemia

Available Forms:

- Nebulized solution: 0.5% (5 mg/mL)
- Prediluted nebulized solution: 0.63 mg/3 mL NS, 1.25 mg/3 mL NS, 2.5 mg/3 mL NS (0.083%)
- Metered-dose inhaler (MDI): 90 µg/puff

Dose and Administration:

Asthma, Anaphylaxis (mild to moderate), Hyperkalemia		
MDI		4 to 8 puffs (inhalation) q 20 minutes PRN with spacer
Nebulizer	weight <20 kg	2.5 mg/dose (inhalation) q 20 minutes
	weight >20 kg	5 mg/dose (inhalation) q 20 minutes
Asthma, Anaphylaxis (severe)		
Continuous nebulizer		0.5 mg/kg per hour continuous inhalation (maximum dose 20 mg/h)
MDI (recommended if intubated)		4 to 8 puffs (inhalation) via ETT q 20 minutes PRN or with spacer if not intubated

Action: Stimulates β_2-adrenergic receptors, causing bronchodilation, tachycardia, vasodilation, movement of potassium from extracellular to intracellular space (serum potassium will fall).

Pharmacokinetics:

Absorption	well absorbed
Distribution	unknown
Metabolism	liver (extensive), tissues
Excretion	urine
Half-life	3 to 8 hours

Pharmacodynamics:

Inhalation

- Onset—5 to 15 minutes
- Peak—1 to 1½ hours
- Duration—4 to 6 hours

Monitoring:

- Monitor SpO_2, blood pressure, breath sounds, and ECG continuously.
- Consider checking potassium concentration, especially if low prior to administration or if high doses of albuterol used.

Adverse Effects:

CNS	tremors, anxiety, insomnia, headache, dizziness, hallucinations, altered smell
EENT	dry nose and throat, irritation of nose and throat, bad taste
RESP	cough, wheezing, dyspnea, bronchospasm (these side effects are rare)
CV	palpitations, tachycardia, hypertension, angina, hypotension, arrhythmias
GI	heartburn, nausea, vomiting, diarrhea
SKIN	flushing, sweating, angioedema

Contraindications: Tachyarrhythmias, severe cardiac disease, or hypersensitivity to albuterol or adrenergic amines

Special Considerations:

- May be combined in same nebulizer with ipratropium bromide
- Increased risk of tachyarrhythmias when combined with theophylline or simultaneous use of other adrenergic agents (eg, terbulatine, dopamine)

Alprostadil (PGE_1)

Classification: Vasodilator, prostaglandin

Indications: Ductal-dependent congenital heart disease (to maintain patency of ductus arteriosus)

- Cyanotic lesions (eg, transposition of great vessels, tricuspid atresia, tetralogy of Fallot)
- Left heart or ascending aortic obstructive lesions (eg, hypoplastic left heart syndrome, critical aortic stenosis, coarctation of aorta, interrupted aortic arch)

Available Forms: Injection: 500 µg/mL

Dose and Administration:

Ductal-Dependent Congenital Heart Disease (all forms)		
IV/IO	Initial	0.05 to 0.1 µg/kg per minute IV/IO infusion
	Maintenance	0.01 to 0.05 µg/kg per minute IV/IO infusion

Actions:

- Acts through PGE_1 receptors to cause vasodilation of *all* arteries and arterioles (including ductus arteriosus)
- Inhibits platelet aggregation
- Stimulates uterine and intestinal smooth muscle

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	wide
Metabolism	endothelium in the lung (90% metabolized in one passage)
Excretion	urine
Half-life	5 to 10 minutes

Pharmacodynamics:

IV/IO

- Onset—within seconds
- Peak—<1 hour (cyanotic lesions); several hours (acyanotic lesions)

Monitoring: Monitor SpO_2, respiratory rate, blood pressure, ECG, and temperature continuously.

Adverse Effects:

CNS	seizures
RESP	apnea (common complication), bronchospasm
CV	vasodilation (common), hypotension, bradycardia, tachycardia, cardiac arrest
GI	gastric outlet obstruction, diarrhea
GU	renal failure
MS	cortical proliferation of long bones (after prolonged treatment, seen as periosteal new bone formation on x-ray)
SKIN	flushing, edema, urticaria
ENDO	hypoglycemia
HEME	disseminated intravascular coagulation, leukocytosis, hemorrhage, thrombocytopenia
ELECT	hypocalcemia
MISC	fever (common)

Precautions:

- Higher dose is associated with increased risk of adverse effects.
- Extravasation may cause tissue sloughing and necrosis.

Special Considerations:

- Drug may also be given via umbilical arterial catheter (UAC) positioned near ductus arteriosus.
- Prostaglandin E_1 should be refrigerated until administered.
- One method for infusion preparation is to multiply 0.3 by the infant's weight in kilograms. The result is the number of milligrams of prostaglandin to add to sufficient diluent (D_5W or NS) to create a solution totaling 50 mL. An infusion rate of 0.5 mL/h controlled by an infusion pump will deliver 0.05 µg/kg per minute.

Amiodarone

Classification: Antiarrhythmic (Class III)

- SVT
- VT (with pulses)
- Pulseless arrest (VF/pulseless VT)

Available Forms: Injection: 50 mg/mL, 15 mg/mL (aqueous solution without benzyl alcohol and polysorbate 80)

Dose and Administration:

SVT, VT (with pulses)	
IV/IO	5 mg/kg IV/IO *load* over 20 to 60 minutes (maximum dose 300 mg), repeat to maximum daily dose 15 mg/kg (2.2 g in adolescents)
Pulseless Arrest (VF/pulseless VT)	
IV/IO	5 mg/kg IV/IO *bolus* (maximum dose 300 mg), can repeat to maximum daily dose 15 mg/kg (2.2 g in adolescents)

Actions:

- Prolongs action potential duration and effective refractory period
- Slows sinus rate
- Prolongs PR and QT intervals
- Noncompetitively inhibits α-adrenergic and β-adrenergic receptors

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	wide
Metabolism	liver
Excretion	bile/feces, urine (minimal)
Half-life	15 to 50 days (oral doses have very long half-life)

Pharmacodynamics:

IV/IO

- Onset—within hours
- Peak—2 to 3 days
- Duration—2 weeks to months after stopping drug

Monitoring: Monitor blood pressure and ECG continuously.

Adverse Effects:

CNS	headache, dizziness, involuntary movement, tremors, peripheral neuropathy, malaise, fatigue, ataxia, paresthesias, syncope
RESP	pulmonary fibrosis, pulmonary inflammation, ARDS (Note: Gasping was reported in neonates as a complication of the benzyl alcohol preservative in non–water soluble form of the drug; water soluble product is not associated with this problem)
CV	*main toxicity:* hypotension, bradycardia, SA node dysfunction, sinus arrest, CHF, prolonged QT interval, torsades de pointes
GI	nausea, vomiting, diarrhea, abdominal pain
SKIN	rash, photosensitivity, blue-gray skin discoloration, alopecia, ecchymosis, toxic epidermal necrolysis, flushing
ENDO	hyperthyroidism, hypothyroidism (common with chronic use)
HEME	coagulation abnormalities

Precautions:

- Routine administration in combination with procainamide (or other agents that prolong QT interval) is *not* recommended without expert consultation.
- Use with caution if hepatic failure is present.
- Amiodarone inhibits cytochrome P450 system and therefore can increase drug concentration and risk of toxicity of a number of agents (eg, diltiazem).

Contraindications: Sinus node dysfunction, 2nd degree or 3rd degree AV block

Special Considerations: Because of its long half-life and potential drug interactions, consultation with a cardiologist is encouraged before using amiodarone outside of the cardiac arrest setting.

Atropine

Classification: Anticholinergic

Indications:

- Symptomatic bradycardia (usually secondary to vagal stimulation)
- Toxins/overdose (eg, organophosphate, carbamate)
- Rapid sequence intubation (RSI): (ie, age <1 year, age 1 to 5 years receiving succinylcholine, age >5 years receiving second dose of succinylcholine)

Available Forms: Injection: 0.05, 0.1, 0.3, 0.4, 0.5, 0.8, 1 mg/mL

Dose and Administration:

Bradycardia (symptomatic)		
IV/IO	0.02 mg/kg IV/IO (minimum dose 0.1 mg, maximum single dose for child is 0.5 mg, maximum single dose for adolescent is 1 mg). May repeat dose once (maximum total dose for child is 1 mg, maximum total dose for adolescent is 2 mg). Larger doses may be needed for treatment of organophosphate poisoning.	
ET	0.04 to 0.06 mg/kg ET	
Toxins/Overdose (eg, organophosphate, carbamate)		
IV/IO	<12 years	0.02 to 0.05 mg/kg IV/IO initially, then repeated IV/IO q 20 to 30 min until muscarinic symptoms reverse
	>12 years	0.05 mg/kg IV/IO initially, then 1 to 2 mg IV/IO q 20 to 30 min until muscarinic symptoms reverse
RSI		
IV/IO	0.01 to 0.02 mg/kg IV/IO (minimum dose 0.1 mg, maximum dose 1 mg)	
IM	0.02 mg/kg IM	

Action:

- Blocks acetylcholine and other muscarinic agonists at parasympathetic neuroeffector sites
- Increases heart rate and cardiac output by blocking vagal stimulation
- Reduces saliva production and increases saliva viscosity
- Causes mydriasis

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	crosses blood-brain barrier
Metabolism	liver
Excretion	urine, unchanged (70% to 90%)
Half-life	2 to 4 hours (longer if age <2 years)

Pharmacodynamics:

IV/IO

- Onset—2 to 4 minutes
- Peak—2 to 4 minutes
- Duration—2 to 6 hours

Monitoring: Monitor SpO_2, blood pressure, and ECG continuously.
Adverse Effects:

CNS	headache, dizziness, involuntary movement, confusion, psychosis, anxiety, coma, flushing, drowsiness, weakness
EENT	blurred vision, photophobia, glaucoma, eye pain, pupil dilation, nasal congestion, dry mouth, altered taste
CV	tachycardia, hypotension, paradoxical bradycardia, angina, premature ventricular contractions, hypertension
GI	nausea, vomiting, abdominal pain, constipation, paralytic ileus, abdominal distention
GU	urinary retention, dysuria
SKIN	rash, urticaria, contact dermatitis, dry skin, flushing, decreased sweating

Precautions:

- To avoid paradoxical bradycardia, do not use less than the minimum dose (ie, 0.1 mg).
- Document clearly if used for patients with head injury, because atropine will distort pupillary exam (causing pupil dilation).

Contraindications: Angle closure glaucoma, tachyarrhythmias, thyrotoxicosis
Special Considerations:

- Drug blocks bradycardic response to hypoxia. Monitor SpO_2 with pulse oximetry.
- Use drug in any child with bradycardia at time of endotracheal intubation.
- Consider using drug to prevent increased oral secretions if ketamine is used.
- Consider using drug to prevent bradycardia when succinylcholine is used in an infant or young child, especially in the presence of hypoxia and acidosis.

Calcium Chloride

Classification: Electrolyte
Indications:

- Hypocalcemia
- Hyperkalemia
- Consider for treatment of hypermagnesemia
- Consider for treatment of calcium channel blocker overdose

Available Forms: Injection: 100 mg/mL (10%)
Dose and Administration:

Hypocalcemia, Hyperkalemia, Hypermagnesemia, Calcium Channel Blocker Overdose	
IV/IO	20 mg/kg (0.2 mL/kg) IV/IO *slow* push during cardiac arrest (if hypocalcemia known or suspected); may repeat if documented or suspected clinical indication persists. Infuse over 30 to 60 minutes for other indications.

Actions:

- Needed for maintenance of nervous, muscular, skeletal systems, enzyme reactions, normal cardiac contractility, blood coagulation
- Affects secretory activity of endocrine and exocrine glands

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	extracellular
Metabolism	liver, bone uptake
Excretion	feces (80%), urine (20%)
Half-life	unknown

Pharmacodynamics:

IV/IO

- Onset—immediate
- Peak—rapid
- Duration—variable

Monitoring: Monitor blood pressure and ECG.

Adverse Effects (note that overdose can produce hypercalcemia and its signs):

CV	hypotension, bradycardia, asystole, shortened QT interval, heart block, cardiac arrest, arrhythmias
SKIN	sclerosis of peripheral veins, venous thrombosis, burn/necrosis (occurs with infiltration of surrounding tissue)
ELECT	hypercalcemia (with overdose)

Precautions:

- Do not use routinely during resuscitation (may contribute to cellular injury).
- Drug is not recommended for routine treatment of asystole or PEA unless hypocalcemia is suspected or documented.
- Avoid rapid administration (may cause adverse cardiovascular effects—eg, bradycardia—particularly if patient is receiving digoxin).

Contraindications: Hypercalcemia, digitalis toxicity, VF (except in the setting of suspected hyperkalemia)

Special Considerations:

- A dose of 20 mg/kg of calcium chloride 10% (0.2 mL/kg) IV or IO is equivalent to 5.4 mg/kg of elemental calcium.
- Central venous administration is preferred if available.
- When infusing calcium and sodium bicarbonate emergently, flush the tubing with NS before and after infusion of each drug to avoid formation of an insoluble precipitate in the catheter lumen.

Dexamethasone

Classification: Corticosteroid

Indications:

- Croup (mild to severe)
- Asthma (mild to moderate)
- Vasogenic cerebral edema (eg, from brain tumor or abscess)

Available Forms:

- Injection: 4, 10 mg/mL
- Elixir: 0.5 mg/5 mL
- Oral solution: 0.1, 1 mg/mL

Dose and Administration:

Croup	
Moderate to severe	0.6 mg/kg PO/IM/IV × 1 dose (maximum dose 16 mg)
Impending respiratory failure	0.6 mg/kg IV (maximum dose 16 mg)
Asthma	
Mild to moderate	0.6 mg/kg PO/IM/IV q 24 hours × 2 doses (maximum dose 16 mg)
Vasogenic Cerebral Edema	
	1 to 2 mg/kg IV/IO *load,* then 1 to 1.5 mg/kg per day divided every 4 to 6 hours (maximum daily dose 16 mg)

Actions:

- Reduces the number and activation of lymphocytes, eosinophils, mast cells, and macrophages and downregulates production and release of proinflammatory cytokines
- Inhibits vascular leak induced by proinflammatory mediators
- Restores disrupted endothelium tight junctions
- Increases expression of β-adrenergic receptors on cell surface, helping to restore responsiveness to catecholamines

Pharmacokinetics:

Absorption	rapid absorption through oral and IM routes (not applicable with IV/IO route of administration)
Distribution	wide distribution; acts at intracellular receptor
Metabolism	liver
Excretion	urine, bile/feces
Half-life	3 to 4½ hours for clearance; pharmacologic effect is much longer

Pharmacodynamics:

	PO	**IM**
Onset	1 hour	<1 hour
Peak	1 to 2 hours	8 hours
Duration	2½ days	6 days

Monitoring: Monitor SpO_2, blood pressure, and ECG.

Adverse Effects:

CNS	depression, headache, irritability, insomnia, euphoria, seizures, psychosis, hallucinations, weakness
EENT	fungal infections, increased intraocular pressure, blurred vision
CV	hypertension, thrombophlebitis, embolism, tachycardia, edema
GI	diarrhea, nausea, abdominal distention, pancreatitis
MS	fractures, osteoporosis
SKIN	flushing, sweating, acne, poor wound healing, ecchymosis, petechiae, hirsutism
ENDO	hypothalamic-pituitary-adrenal axis suppression, hyperglycemia, sodium and fluid retention
HEME	hemorrhage, thrombocytopenia
ELECT	hypokalemia

Special Considerations: Use for more than a few days can cause hypertension and hyperglycemia and increased risk of gastric bleeding.

Dextrose (Glucose)

Classification: Carbohydrate
Indications: Hypoglycemia
Available Forms: Injection: D_5W (0.05 g/mL), $D_{10}W$ (0.1 g/mL), $D_{50}W$ (0.5 g/mL)
Dose and Administration:

Hypoglycemia	
IV/IO	0.5 to 1 g/kg IV/IO

Concentration	*Dose*
$D_{50}W$	1 to 2 mL/kg
$D_{25}W$	2 to 4 mL/kg
$D_{10}W$	5 to 10 mL/kg
D_5W	10 to 20 mL/kg

Action: Essential for cellular respiration, the process by which chemical energy of "food" molecules is metabolized to produce ATP
Monitoring: Use rapid glucose test to rapidly confirm suspicion of hypoglycemia and monitor response to therapy.
Adverse Effects:

SKIN	sclerosis of veins (with hypertonic glucose concentrations)
ENDO	hyperglycemia, hyperosmolarity

Precautions: Do not administer drug routinely during resuscitation unless hypoglycemia is documented.
Special Considerations:

- Bolus glucose therapy for treatment of documented hypoglycemia should generally be followed by a continuous glucose infusion.
- Maximum recommended concentration for bolus administration is $D_{25}W$ (can be prepared by mixing $D_{50}W$ 1:1 with sterile water).
- Maximum concentration for newborn administration is $D_{12.5}W$ (0.125 g/mL).

Diphenhydramine

Classification: Antihistamine
Indications: Anaphylactic shock (after administration of epinephrine)
Available Forms: Injection: 10, 50 mg/mL
Dose and Administration:

Anaphylactic Shock	
IV/IO/IM	1 to 2 mg/kg IV/IO/IM q 4 to 6 hours (maximum dose 50 mg)

Actions:

- Competes with histamine for H_1-receptor sites
- Decreases allergic response by blocking histamine

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	wide
Metabolism	liver (95%)
Excretion	urine
Half-life	2 to 8 hours

Pharmacodynamics:

	IM	IV/IO
Onset	30 minutes	immediate
Peak	1 to 4 hours	unknown
Duration	4 to 8 hours	4 to 8 hours

Monitoring: Monitor SpO_2 and blood pressure continuously.

Adverse Effects:

CNS	dizziness, drowsiness, poor coordination, fatigue, anxiety, euphoria, confusion, paresthesia, neuritis, seizures, dystonic reaction, hallucinations, sedation (can cause paradoxical excitation in children)
EENT	blurred vision, pupil dilation, tinnitus, nasal stuffiness, dry nose/mouth/throat
CV	hypotension, palpitations, tachycardia
RESP	chest tightness
GI	nausea, vomiting, diarrhea
GU	urinary retention, dysuria, frequency
SKIN	photosensitivity, rash
HEME	thrombocytopenia, agranulocytosis, hemolytic anemia
MISC	anaphylaxis

Precautions: Drug may exacerbate angle closure glaucoma, hyperthyroidism, peptic ulcer, and urinary tract obstruction.

Dobutamine

Classification: Catecholamine, β-adrenergic agent

Indications:

- Congestive heart failure
- Cardiogenic shock

Available Forms:

- Injection: 12.5 mg/mL
- Premixed dilutions: 1 mg/mL, 2 mg/mL, 4 mg/mL

Dose and Administration:

Congestive Heart Failure, Cardiogenic Shock	
IV/IO	2 to 20 µg/kg per minute IV/IO infusion (titrated to desired effect)

Actions:

- Stimulates β_1-receptors (predominant effect)
  - — Increases heart rate (SA node effect)
  - — Increases myocardial contractility, automaticity, and conduction velocity (ventricular effect)
- Stimulates β_2-receptors, which increases heart rate and causes vasodilation
- Stimulates and inhibits α-receptors, which tend to cancel out vasoconstriction, but dobutamine has intrinsic α-adrenergic blocking effects, increasing the risk of hypotension from vasodilation

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	extracellular fluid
Metabolism	liver, kidney
Excretion	urine
Half-life	2 minutes

Pharmacodynamics:

IV/IO

- Onset—1 to 2 minutes
- Peak—10 minutes
- Duration—<10 minutes when infusion stopped

Monitoring: Monitor blood pressure and ECG continuously.

Adverse Effects:

CNS	anxiety, headache, dizziness
CV	hypotension, hypertension, palpitations, tachyarrhythmias, premature ventricular contractions, angina
GI	nausea, vomiting, mucositis
HEME	myelosuppression, neutropenia, thrombocytopenia, anemia

Precautions:

- Extravasation of dobutamine may produce tissue ischemia and necrosis.
- Do not mix with sodium bicarbonate.

Special Considerations:

- Drug is inactivated in alkaline solutions.
- Consider carefully in vasodilated septic shock because drug tends to further lower systemic vascular resistance.

Dopamine

Classification: Catecholamine, vasopressor, inotrope

Indications:

- Cardiogenic shock
- Distributive shock

Available Forms:

- Injection: 40, 80, 160 mg/mL
- Prediluted in D_5W: 0.8, 1.6, 3.2 mg/mL

Dose and Administration:

Cardiogenic Shock, Distributive Shock	
IV/IO	2 to 20 µg/kg per minute IV/IO infusion (titrate to desired effect)

Actions:

- Stimulates α-adrenergic receptors
  - — Increases SVR (via constriction of arterioles)
- Stimulates β_1-adrenergic receptors
  - — Increases heart rate (SA node effect)
  - — Increases myocardial contractility, automaticity, and conduction velocity (ventricular effect)
- Stimulates β_2-adrenergic receptors
  - — Increases heart rate
  - — Lowers systemic vascular resistance
- Stimulates dopaminergic receptors
  - — Causes renal and splanchnic vasodilation
  - — Increases renal sodium and water loss by direct renal tubular action

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	extracellular space
Metabolism	liver, kidney
Excretion	urine
Half-life	2 minutes

Pharmacodynamics:

IV/IO

- Onset—1 to 2 minutes
- Peak—10 minutes
- Duration—<10 minutes when infusion stopped

Monitoring: Monitor blood pressure and ECG.

Adverse Effects:

CNS	headache
RESP	dyspnea
CV	palpitations, premature ventricular contractions, SVT, VT, hypertension, peripheral vasoconstriction
GI	nausea, vomiting, diarrhea
GU	acute renal failure
SKIN	local necrosis (with infiltration), gangrene

Precautions:

- High infusion rates (>20 µg/kg per minute) may produce peripheral, renal, and splanchnic vasoconstriction and ischemia.
- Do not mix with sodium bicarbonate.
- Thyroid function may be affected with prolonged use because dopamine may inhibit TSH release.

Special Considerations:

- High concentrations and large-volume infusions should be administered via a central venous catheter.
- Drug is inactivated in alkaline solutions.
- Effects are dose dependent: low infusions (1 to 5 µg/kg per minute) usually stimulate dopaminergic and β-adrenergic receptors; α-adrenergic effects become more prominent as infusion rate is increased.

Epinephrine

Classification: Catecholamine, vasopressor, inotrope
Indications:

- Anaphylaxis
- Asthma
- Bradycardia (symptomatic)
- Croup
- Pulseless arrest
- Shock (hypotensive)
- Toxins/overdose (eg, β-adrenergic blocker, calcium channel blocker)

Available Forms:

- Injection: 1:1000 aqueous (1 mg/mL), 1:10 000 aqueous (0.1 mg/mL)
- IM auto-injector: 0.3 mg (0.3 mL 1:1000 solution)
- Child IM junior auto-injector (for patient weight 10 to 30 kg): 0.15 mg (0.3 mL 1:2000 solution)
- Racemic solution: 2.25%

Dose and Administration:

Anaphylaxis	
IM	0.01 mg/kg (0.01 mL/kg) 1:1000 IM in thigh q 15 minutes PRN (maximum dose 0.5 mg) or
	IM auto-injector 0.3 mg (for patient weight ≥30 kg) or child IM junior auto-injector 0.15 mg (for patient weight 10 to 30 kg)
IV/IO	• 0.01 mg/kg (0.1 mL/kg) 1:10 000 IV/IO q 3 to 5 minutes (maximum dose 1 mg) if hypotension • If hypotension persists despite fluid administration and IV/IO injection, consider continuous IV/IO infusion of 0.1 to 1 µg/kg per minute
Asthma	
SQ	0.01 mg/kg (0.01 mL/kg) 1:1000 SQ q 15 minutes (maximum dose 0.5 mg; 0.5 mL)
Bradycardia (symptomatic)	
IV/IO	0.01 mg/kg (0.1 mL/kg) 1:10 000 IV/IO q 3 to 5 minutes (maximum dose 1 mg; 1 mL)
Croup	
Nebulizer	• 0.25 mL racemic solution (2.25%) mixed in 3 mL NS by inhaled nebulizer if moderate to severe illness (ie, stridor at rest) in infants or young children; up to 0.5 mL mixed in 3 mL NS for older children *or* • 3 mL 1:1000 by inhaled nebulizer (can mix in 3 mL NS)
Pulseless Arrest	
IV/IO	0.01 mg/kg (0.1 mL/kg) 1:10 000 IV/IO q 3 to 5 minutes (maximum IV/IO dose 1 mg)
ET	0.1 mg/kg (0.1 mL/kg) 1:1000 ET q 3 to 5 minutes

Shock (hypotensive)	
IV/IO infusion	0.1 to 1 µg/kg per minute IV/IO infusion (consider higher doses if needed)
Toxins/Overdose (eg, β-adrenergic blocker, calcium channel blocker)	
IV/IO	0.01 mg/kg (0.1 mL/kg) 1:10 000 IV/IO (maximum IV/IO dose 1 mg); if no response, consider higher doses up to 0.1 mg/kg (0.1 mL/kg) 1:1000 IV/IO
IV/IO infusion	0.1 to 1 µg/kg per minute IV/IO infusion (consider higher doses if hypotension refractory to this dose)

Actions:

- Stimulates α-adrenergic receptors at higher infusion rates, usually >0.3 µg/kg per minute *in infants and young children.* Older children need lower infusion rates to achieve vasoconstriction (response is dose-dependent but difficult to predict in individual patients).
  - — Increases SVR (via constriction of arterioles, recognized by increase in diastolic blood pressure)
- Stimulates β_1-adrenergic receptors
  - — Increases heart rate (SA node effect)
  - — Increases myocardial contractility, automaticity, and conduction velocity (SA node, AV node, and ventricular effect)
- Stimulates β_2-adrenergic receptors (predominates at lower infusion rates, usually ≤0.3 µg/kg per minute)
  - — Increases heart rate (SA node effect)
  - — Causes bronchodilation
  - — Causes vasodilation of arterioles; recognize fall in SVR by decrease in diastolic blood pressure. Data suggests that vasodilation preferentially occurs in the skeletal muscle vascular beds and infusion may result in a relative decrease in splanchnic perfusion when used in shock.

Pharmacokinetics:

Absorption	IM absorption is affected by perfusion (not applicable with IV/IO route of administration)
Distribution	unknown
Metabolism	liver, kidney, endothelium
Excretion	unknown
Half-life	2 to 4 minutes

Pharmacodynamics:

	IM	IV/IO	(Inhalation)
Onset	5 to 10 minutes	immediate	1 minute
Peak	unknown	within 1 minute	unknown

Monitoring: Monitor SpO_2, blood pressure, and ECG continuously.

Adverse Effects:

CNS	tremors, anxiety, insomnia, headache, dizziness, weakness, drowsiness, confusion, hallucinations, intracranial hemorrhage (from severe hypertension)
RESP	dyspnea
CV	arrhythmias (especially tachyarrhythmias, eg, SVT and VT), palpitations, tachycardia, hypertension, ST-segment elevation, postresuscitation myocardial dysfunction
GI	nausea, vomiting
GU	renal vascular ischemia
ENDO	hyperglycemia, postresuscitation hyperadrenergic state

ELECT	hypokalemia (direct effect to move potassium intracellularly resulting from β_2-adrenergic stimulation; may be used to treat hyperkalemia)
MISC	increased lactate (ie, independent of any change in organ perfusion as part of the gluconeogenesis response, making use of lactate as a marker of ischemia more difficult)

Precautions:

- High doses produce vasoconstriction and may compromise organ perfusion.
- Low doses may increase cardiac output with redirection of blood flow to skeletal muscles and decrease renal and splanchnic blood flow.
- Myocardial oxygen requirements are increased (due to increased heart rate, myocardial contractility, and with higher doses, increased SVR).
- Tissue ischemia and necrosis may result if IV infiltration occurs.
- Central venous access is preferred for administration.
- Catecholamines are inactivated in alkaline solutions.
- Observe at least 2 hours post croup treatment for "rebound" (ie, recurrence of stridor).

Contraindications: Cocaine-induced VT

Special Considerations: When given IM in anaphylaxis, data shows that best absorption occurs from thigh rather than deltoid muscle injection. Subcutaneous administration is not recommended for treatment of anaphylaxis because absorption is delayed when compared with IM route.

Furosemide

Classification: Loop diuretic

Indications:

- Pulmonary edema
- Fluid overload

Available Forms: Injection: 10 mg/mL

Dose and Administration:

Pulmonary Edema, Fluid Overload	
IV/IM	1 mg/kg IV/IM (usual maximum dose 20 mg for patient not chronically on loop diuretics)

Actions:

- Acts on ascending limb of loop of Henle inhibiting reabsorption of sodium and chloride, causing excretion of sodium, chloride, calcium, magnesium, and water; increased potassium excretion occurs in distal tubule in exchange for sodium
- Increases excretion of potassium in distal tubule as indirect effect

Pharmacokinetics:

Absorption	IM absorption not documented (not applicable with IV/IO route of administration)
Distribution	unknown
Metabolism	liver (30% to 40%); most excreted unchanged
Excretion	urine, feces
Half-life	½ to 1 hour

Pharmacodynamics:

	PO	IM	IV
Onset	½ to 1 hour	½ hour	5 minutes
Peak	1 to 2 hours	Unknown	½ hour
Duration	6 to 8 hours	4 to 8 hours	2 hours

Monitoring:

- Monitor blood pressure and ECG.
- Monitor blood glucose, BUN, uric acid, CBC, ABG.
- Monitor electrolytes: potassium, sodium, chloride, calcium, magnesium, and total CO_2.

Adverse Effects:

CNS	headache, fatigue, weakness, vertigo, paresthesias
EENT	hearing loss, ear pain, tinnitus, blurred vision, dry mouth, oral irritation
CV	orthostatic hypotension, angina, ECG changes (from electrolyte abnormalities), circulatory collapse
GI	nausea, vomiting, diarrhea, abdominal cramps, gastric irritation, pancreatitis
GU	polyuria, renal failure, glycosuria
MS	muscle cramps, stiffness
SKIN	pruritus, purpura, Stevens-Johnson syndrome, sweating, photosensitivity, urticaria
ENDO	hyperglycemia
HEME	thrombocytopenia, agranulocytosis, leucopenia, anemia, neutropenia
ELECT	hypokalemia, hypochloremia, hypomagnesemia, hyperuricemia, hypocalcemia, hyponatremia
MISC	metabolic alkalosis

Special Considerations: Hypokalemia may be significant and requires close monitoring and replacement therapy.

Hydrocortisone

Classification: Corticosteroid
Indications: Adrenal insufficiency (may be associated with septic shock)
Available Forms: Sodium succinate injectable in 100, 250, 500, 1000 mg/vial
Dose and Administration:

Adrenal Insufficiency	
IV/IO	2 mg/kg IV/IO bolus (maximum dose 100 mg)

Actions:

- Reduces the number and activation of lymphocytes, eosinophils, mast cells, and macrophages, which downregulates the production and release of proinflammatory cytokines
- Inhibits vascular leak induced by proinflammatory mediators
- Restores disrupted endothelial tight junctions
- Decreases mucus secretion
- Increases expression of β-adrenergic receptors on cell surface, helping to restore responsiveness to catecholamines

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	widely distributed; acts at intracellular receptor
Metabolism	liver (extensive)
Excretion	urine
Half-life	3 to 5 hours

Pharmacodynamics:

IV/IO

- Onset—rapid
- Peak—unknown
- Duration—8 to 24 hours

Adverse Effects:

CNS	depression, headache, mood changes
EENT	fungal infections, increased intraocular pressure, blurred vision
CV	hypertension
GI	diarrhea, nausea, abdominal distention, peptic ulcer
MS	fractures, osteoporosis, weakness
SKIN	flushing, sweating, thrombophlebitis, edema, acne, poor wound healing, ecchymosis, petechiae, pruritis
ENDO	hyperglycemia, suppression of hypothalamic-pituitary axis
HEME	hemorrhage, thrombocytopenia, hypercoagulability
MISC	increased risk of infection

Special Considerations: Consider measuring cortisol concentration before use in children with shock. Some centers perform a cosyntropin stimulation test before hydrocortisone administration.

Inamrinone

Classification: Phosphodiesterase inhibitor, inodilator
Indications: Myocardial dysfunction and increased SVR/PVR (eg, cardiogenic shock with high SVR, postcardiac surgery CHF)
Available Forms: Injection: 5 mg/mL
Dose and Administration:

Myocardial Dysfunction and Increased SVR/PVR	
IV/IO	loading dose of 0.75 to 1 mg/kg IV/IO slow bolus over 5 minutes (give over longer period if patient is unstable), may repeat twice (maximum total loading dose 3 mg/kg)
	5 to 10 µg/kg per minute IV/IO infusion

Actions:

- Increases myocardial contractility
- Reduces preload and afterload by relaxation of vascular smooth muscle

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	unknown
Metabolism	liver (50%)
Excretion	urine (10% to 40% unchanged), metabolites (60% to 90%)
Half-life	2 to 10 hours

Pharmacodynamics:

IV/IO

- Onset—2 to 5 minutes
- Peak—10 minutes
- Duration—variable

Monitoring: Monitor SpO_2, blood pressure, and ECG continuously.

Adverse Effects:

RESP	hypoxemia (from increased V/Q mismatch)
CV	hypotension, arrhythmias, angina
GI	nausea, vomiting, abdominal pain, hepatotoxicity, ascites, jaundice
SKIN	allergic reactions, irritation to veins
HEME	thrombocytopenia

Precautions:

- Hypovolemia may worsen hypotensive effects of drug.
- Drug may increase platelet destruction. Thrombocytopenia is more frequent and severe with inamrinone than with milrinone.
- Drug may accumulate in renal failure and in patients with low cardiac output.
- Drug can be co-infused with dextrose solutions but should not be primarily diluted in a dextrose solution.

Special Considerations: Loading dose may cause significant hypotension. If patient is hemodynamically unstable, give the loading dose slowly and monitor blood pressure closely. Be prepared to administer isotonic crystalloid (and possible vasopressors) as needed to treat hypotension.

Ipratropium Bromide

Classification: Anticholinergic, bronchodilator

Indications: Asthma

Available Forms:

- Nebulized solution: 0.02% (500 µg/2.5 mL)
- MDI: 18 µg/puff

Dose and Administration:

Asthma	
Nebulizer	250 to 500 µg (inhaled) q 20 minutes × 3 doses

Actions:

- Blocks action of acetylcholine at parasympathetic sites in bronchial smooth muscle, resulting in bronchodilation
- Inhibits secretions from serous and seromucous glands lining the nasal mucosa

Pharmacokinetics:

Absorption	minimal
Distribution	does not cross blood-brain barrier
Metabolism	liver (minimal)
Excretion	unknown
Half-life	2 hours

Pharmacodynamics:

Inhaled (INH)

- Onset—1 to 15 minutes
- Peak—1 to 2 hours
- Duration—3 to 6 hours

Monitoring: Monitor SpO_2 continuously.

Adverse Effects:

CNS	anxiety, dizziness, headache, nervousness
EENT	dry mouth, blurred vision (pupillary dilation)
RESP	cough, worsening bronchospasm
CV	palpitations
GI	nausea, vomiting, abdominal cramps
SKIN	rash

Special Considerations:

- Ipratropium is not absorbed into the bloodstream; its cardiovascular side effects are minimal.
- Inhaled ipratropium may cause pupillary dilation due to inadvertent deposition of nebulized solution in the eyes.

Lidocaine

Classification: Antiarrhythmic (Class IB)

Indications:

- VF/pulseless VT
- Wide-complex tachycardia (with pulses)
- Rapid sequence intubation (RSI) (ie, ICP protection)

Available Forms: Injection and infusion prepared in D_5W: 0.2% (2 mg/mL), 0.4% (4 mg/mL), 0.8% (8 mg/mL)

Dose and Administration:

VF/Pulseless VT, Wide-Complex Tachycardia (with pulses)		
IV/IO	Initial	1 mg/kg IV/IO loading bolus
	Maintenance	20 to 50 µg/kg per minute IV/IO infusion (repeat bolus dose if infusion initiated >15 minutes after initial bolus therapy)
ET		2 to 3 mg/kg ET
RSI		
IV/IO	1 to 2 mg/kg IV/IO	

Actions:

- Increases electrical stimulation threshold of ventricle and His-Purkinje system (stabilizing cardiac membrane and decreasing automaticity)
- Reduces intracranial pressure through inhibition of sodium channels in neurons, which reduces metabolic activity

Pharmacokinetics:

Absorption	(not applicable with IV/IO administration)
Distribution	erythrocytes, vascular endothelium
Metabolism	liver, active metabolites
Excretion	urine
Half-life	biphasic (8 minutes, 1 to 3 hours)

Pharmacodynamics:

IV/IO

- Onset—1 to 2 minutes
- Peak—unknown
- Duration—10 to 20 minutes because of rapid redistribution; terminal elimination 1½ to 2 hours

Monitoring: Monitor blood pressure and ECG continuously.

Adverse Effects:

CNS	seizures (high concentrations), headache, dizziness, involuntary movement, confusion, tremor, drowsiness, euphoria
EENT	tinnitus, blurred vision
CV	hypotension, myocardial depression, bradycardia, heart block, arrhythmias, cardiac arrest
RESP	dyspnea, respiratory depression or arrest
GI	nausea, vomiting
SKIN	rash, urticaria, edema, swelling, phlebitis at IV site

Precautions: High plasma concentration may cause myocardial and circulatory depression.

Contraindication: Wide-complex ventricular escape beats associated with bradycardia, high-degree heart block

Special Considerations:

- Reduce infusion dose if severe CHF or low cardiac output is compromising hepatic and renal blood flow.
- Drug may decrease ICP response during laryngoscopy for RSI.
- Drug attenuates intraocular pressure response during laryngoscopy for RSI.

Magnesium Sulfate

Classification: Electrolyte, bronchodilator

Indications:

- Asthma (refractory status asthmaticus)
- Torsades de pointes
- Hypomagnesemia

Available Forms: Injection: 100 mg/mL (0.8 mEq/mL), 125 mg/mL (1 mEq/mL), 250 mg/mL (2 mEq/mL), 500 mg/mL (4 mEq/mL)

Dose and Administration:

Asthma (refractory status asthmaticus), **Torsades de Pointes, Hypomagnesemia**	
IV/IO	• 25 to 50 mg/kg IV/IO bolus in pulseless VT with torsades • 25 to 50 mg/kg IV/IO over 10 to 20 minutes for VT with pulses associated with torsades or hypomagnesemia • 25 to 50 mg/kg IV/IO by slower infusion (15 to 30 minutes) for treatment of status asthmaticus • maximum dose 2 g

Actions:

- Inhibits calcium uptake, thereby causing smooth muscle relaxation
- Exerts antiarrhythmic action

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	wide
Metabolism	taken up by cells and bone
Excretion	urine
Half-life	unknown

Pharmacodynamics:

IV/IO

- Onset—immediate
- Peak—depends on duration of infusion
- Duration—30 minutes

Monitoring: Monitor ECG continuously and SpO_2 and blood pressure frequently.

Adverse Effects (most are related to hypermagnesemia):

CNS	confusion, sedation, depressed reflexes, flaccid paralysis, weakness
RESP	respiratory depression
CV	hypotension, bradycardia, heart block, cardiac arrest (may develop with rapid administration)
GI	nausea, vomiting
MS	cramps
SKIN	flushing, sweating
ELECT	hypermagnesemia

Precautions: Rapid bolus may cause severe hypotension and bradycardia.

Contraindication: Renal failure

Special Considerations: Have calcium chloride (or calcium gluconate) available if needed to reverse magnesium toxicity.

Methylprednisolone

Classification: Corticosteroid

Indications:

- Asthma (status asthmaticus)
- Anaphylactic shock

Available Forms: Injection: 40, 125, 500, 1000, 2000 mg

Dose and Administration:

Asthma (status asthmaticus), Anaphylactic Shock		
IV/IO/IM	Load	2 mg/kg IV/IO/IM (maximum 80 mg) Note: must use acetate salt IM
IV	Maintenance	0.5 mg/kg IV q 6 hours or 1 mg/kg q 12 hours up to 120 mg/day

Actions:

- Reduces the number and activation of lymphocytes, eosinophils, mast cells, and macrophages, resulting in downregulation of the production and release of proinflammatory cytokines
- Inhibits vascular leak induced by proinflammatory mediators
- Restores disrupted endothelial tight junctions
- Decreases mucus secretion
- Increases expression of β-adrenergic receptors on cell surface, helping to restore responsiveness to catecholamines

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	wide distribution; binds to intracellular steroid receptor
Metabolism	liver (extensive)
Excretion	urine
Half-life	3 to 5 hours for clearance; duration of effect is longer

Pharmacodynamics:

IV/IO

- Onset: rapid
- Peak: unknown
- Duration: 1 to 2 days

Adverse Effects:

CNS	depression, headache, mood changes, weakness
CV	hypertension, embolism
GI	hemorrhage, diarrhea, nausea, abdominal distention, pancreatitis, peptic ulcer
MS	fractures, osteoporosis, arthralgia
ENDO	hyperglycemia
HEME	hemorrhage, thrombocytopenia, transient leukocytosis
MISC	anaphylaxis (rare)

Special Considerations: Acetate salt is recommended for IM use.

Milrinone

Classification: Phosphodiesterase inhibitor, inodilator
Indications: Myocardial dysfunction and increased SVR/PVR (eg, cardiogenic shock with high SVR, postcardiac surgery, CHF)
Available Forms:

- Injection: 1 mg/mL
- Premixed injection in D_5W: 200 µg/mL

Dose and Administration:

Myocardial Dysfunction and Increased SVR/PVR	
IV/IO	• Loading dose of 50 to 75 µg/kg IV/IO over 10 to 60 minutes • Infusion of 0.5 to 0.75 µg/kg per minute IV/IO

Actions:

- Increases myocardial contractility
- Reduces preload and afterload by relaxation of vascular smooth muscle

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	unknown
Metabolism	liver (12%)
Excretion	urine, unchanged (83%), metabolites (12%)
Half-life	2.4 hours

Pharmacodynamics:

IV/IO

- Onset—2 to 5 minutes
- Peak—10 minutes
- Duration—variable (1½ to 5 hours)

Monitoring:

- Monitor blood pressure and ECG continuously.
- Routinely monitor platelet count.

Adverse Effects:

CNS	headache, tremor
CV	hypotension, ventricular arrhythmias, angina
GI	nausea, vomiting, abdominal pain, hepatotoxicity, jaundice
HEME	thrombocytopenia
ELECT	hypokalemia

Precautions:

- Hypovolemia may worsen hypotensive effects of drug.
- Drug has shorter half-life and less effect on platelets compared with inamrinone.
- Drug may accumulate in patients with renal failure or low cardiac output.

Special Considerations: Longer infusion times reduce risk of hypotension.

Naloxone

Classification: Opioid receptor antagonist
Indications: Narcotic (opiate) reversal
Available Forms: Injection: 0.4, 1 mg/mL
Dose and Administration:

Narcotic (opiate) Reversal
Note: Total reversal is indicated for narcotic toxicity secondary to overdose; significantly smaller doses are required for patients with respiratory depression associated with therapeutic narcotic use.

- Total reversal: 0.1 mg/kg IV/IO/IM/SQ bolus q 2 minutes PRN (maximum dose 2 mg)
- Total reversal *not* required: 1 to 5 µg/kg IV/IO/IM/SQ (titrated to effect)
- 0.002 to 0.16 mg/kg per hour IV/IO infusion

Action: Competes with opiates at opioid receptor sites (reversing opioid effects)
Pharmacokinetics:

Absorption	rapid absorption after IM, SQ administration (not applicable with IV/IO route of administration)
Distribution	rapid
Metabolism	liver
Excretion	urine
Half-life	1 hour (up to 3 hours in neonates)

Pharmacodynamics:

IV/IO
- Onset—1 minute
- Peak—unknown
- Duration—20 to 60 minutes (variable and dose dependent)

Monitoring: Monitor SpO_2, blood pressure, and ECG continuously.
Adverse Effects:

CNS	seizures, drowsiness, nervousness
RESP	hyperpnea, pulmonary edema
CV	VF/VT, tachycardia, hypertension, asystole (especially if total reversal dose administered)
GI	nausea, vomiting

Precautions:

- Repeat dosing is often required because half-life of naloxone is often shorter than half-life of opioid being reversed.
- Administration to infants of addicted mothers may precipitate seizures or other withdrawal symptoms.
- In overdose patients, establish effective assisted ventilation before naloxone administration to avoid excessive sympathetic reaction.
- Drug reverses effects of narcotic analgesics; consider administration of nonopioid analgesics for treatment of pain.

Special Considerations: Drug exerts some analgesic effects.

Nitroglycerin

Classification: Vasodilator, antihypertensive

Indications:

- Congestive heart failure
- Cardiogenic shock

Available Forms:

- Injection: 0.5, 5, 10 mg/mL
- Prediluted injection in D_5W: 100 µg/mL, 200 µg/mL, 400 µg/mL

Dose and Administration:

Congestive Heart Failure, Cardiogenic Shock	
IV/IO	0.25 to 0.5 µg/kg per minute IV/IO infusion, may increase by 0.5 to 1 µg/kg per minute q 3 to 5 minutes PRN to 1 to 5 µg/kg per minute (maximum dose 10 µg/kg per minute in children) In adolescents start with 10 to 20 µg *per minute* (Note: This dose is *not* per kg per minute) and increase by 5 to 10 µg per minute every 5 to 10 minutes to maximum of 200 µg *per minute*

Action: Releases nitric oxide, which stimulates cGMP production; cGMP is an intracellular messenger that results in vascular smooth muscle relaxation. Action is greatest in venous system and pulmonary vascular bed, with relatively less effect on systemic arterial resistance.

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	unknown
Metabolism	liver (extensive); no active metabolites
Excretion	urine
Half-life	1 to 4 minutes

Pharmacodynamics:

IV/IO

- Onset—1 to 2 minutes
- Peak—unknown
- Duration—3 to 5 minutes

Monitoring: Monitor blood pressure and ECG continuously.

Adverse Effects:

CNS	headache, dizziness
RESP	hypoxemia (due to increased V/Q mismatch)
CV	postural hypotension, tachycardia, cardiac arrest, syncope, paradoxical bradycardia
SKIN	flushing, pallor, sweating

Norepinephrine

Classification: Inotrope, vasopressor, catecholamine
Indications: Hypotensive (usually distributive) shock (ie, associated with low systemic vascular resistance and unresponsive to fluid resuscitation)
Available Forms: Injection: 1 mg/mL
Dose and Administration:

Hypotensive Shock	
IV/IO	0.1 to 2 µg/kg per minute IV/IO infusion (titrate to desired effect)

Actions:

- Activates α-adrenergic receptors (increased smooth muscle tone)
- Activates myocardial β_1-adrenergic receptors (increased contractility and heart rate). The heart rate effect is blunted by baroreceptor stimulation that results from the vasoconstrictive effects.

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	extracellular space
Metabolism	liver, kidney, sympathetic nerves
Excretion	urine
Half-life	2 to 4 minutes

Pharmacodynamics:

IV/IO

- Onset—<30 seconds
- Peak—5 to 10 minutes
- Duration—≤10 minutes after stopping infusion

Monitoring: Monitor blood pressure and ECG continuously.
Adverse Effects:

CNS	headache, anxiety
RESP	respiratory distress
CV	hypertension, tachycardia, bradycardia, arrhythmias
GU	renal failure
SKIN	local necrosis (infiltration)

Precautions:

- If IV infiltration occurs, may produce severe tissue ischemia and necrosis due to prominent vasoconstrictive effects.
- Do not mix with sodium bicarbonate.

Special Considerations:

- Ideally should be administered via a central venous catheter.
- Drug is inactivated in alkaline solutions.

Oxygen

Classification: Element, gas

Indications:

- Hypoxia/hypoxemia
- Respiratory distress/respiratory failure
- Shock
- Trauma
- Cardiopulmonary failure
- Cardiac arrest
- Rapid sequence intubation (RSI) (ie, preoxygenation)

Available Forms: 100%

Dose and Administration:

Hypoxia/Hypoxemia, Respiratory Distress/Respiratory Failure, Shock, Trauma, Cardiopulmonary Failure, Cardiac Arrest
Administer 100% O_2 initially via high-flow O_2 delivery system; titrate to desired effect
RSI (preoxygenation)
Administer 100% O_2 via well-fitted face mask for at least 3 minutes (if spontaneous ventilations)

Delivery System	Oxygen (%)	Flow Rate (L/minute)
Low-flow System		
Nasal cannula	22 to 60 (depending on patient size and flow rate)	0.25 to 4
Oxygen mask	35 to 60	6 to 10
High-flow System		
Face tent	<40	10 to 15
Oxygen hood	80 to 90	10 to 15
Oxygen tent	>50	>10
Partial rebreathing mask with reservoir	50 to 60	10 to 12
Nonrebreathing mask with reservoir	95	10 to 15
Venturi mask	25 to 60 (mask specific)	variable

Actions:

- Increases arterial oxygen saturation
- Increases arterial oxygen content
- May improve tissue oxygen delivery if cardiac output is adequate

Monitoring: Monitor SpO_2 continuously.

Adverse Effects:

CNS	headache (high-flow rates)
EENT	dry mucous membranes (high-flow rates)
RESP	airway obstruction (due to drying of secretions)
GI	gastric distention (high-flow rates)

Precautions:

- Insufficient flow rates delivered via oxygen mask, oxygen hood, and oxygen tent may cause CO_2 retention.
- Oxygen delivery systems can cause obstruction of the small airways due to drying of secretions.

Special Considerations:

- Titrate therapy based on SpO_2 once adequate oxygen delivery has been achieved.
- Tight mask seal and high flow rates delivered via rebreathing systems are required to deliver maximum oxygen concentration.
- Collapsed reservoir bag on nonrebreathing system indicates air leak or inadequate flow rate.
- Add humidification to oxygen delivery systems as soon as feasible.
- In children with some cyanotic heart conditions with single ventricle physiology (eg, following surgical palliation before correction of hypoplastic left heart syndrome), use oxygen with caution. In these children the balance of systemic versus pulmonary blood flow can be substantially altered by effects of oxygen administration on pulmonary vascular resistance. Seek expert advice before use if you are unsure.

Procainamide

Classification: Antiarrhythmic (class IA)

- SVT
- Atrial flutter
- VT (with pulses)

Available Forms: Injection: 100, 500 mg/mL

Dose and Administration:

SVT, Atrial Flutter, VT (with pulses)	
IV/IO	15 mg/kg IV/IO load over 30 to 60 minutes

Actions:

- Depresses excitability of cardiac muscle
- Slows conduction in atrium, bundle of His, and ventricle
- Increases refractory period

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	rapid
Metabolism	liver to active metabolite (NAPA)
Excretion	urine, unchanged (50% to 70%)
Half-life	2.5 to 4.5 hours (procainamide); approximately 6 to 8 hours (NAPA)

Pharmacodynamics:

IV/IO

- Onset—rapid
- Peak—15 to 60 minutes
- Duration—3 to 6 hours

Monitoring: Monitor blood pressure and ECG continuously with focus on QT interval.

Adverse Effects:

CNS	headache, dizziness, confusion, psychosis, restlessness, irritability, weakness
CV	hypotension, negative inotropic effects, prolonged QT interval, torsades de pointes, heart block, cardiac arrest
GI	nausea, vomiting, diarrhea, hepatomegaly
SKIN	rash, urticaria, edema, swelling, pruritus, flushing
HEME	systemic lupus erythematosus syndrome, agranulocytosis, thrombocytopenia, neutropenia, hemolytic anemia

Precautions:

- Seek expert consultation when using this agent.
- Routine use in combination with amiodarone (or other drugs that prolong QT interval) is not recommended without expert consultation.
- Risk of hypotension and negative inotropic effects increases with rapid administration. Therefore, this drug is not an appropriate agent for treatment of VF or pulseless VT.
- Reduce dose for patients with poor renal or cardiac function.

Special Considerations: Monitor procainamide and NAPA concentrations.

Sodium Bicarbonate

Classification: Alkalinizing agent, electrolyte

Indications:

- Metabolic acidosis (severe)
- Hyperkalemia
- Sodium channel blocker overdose (eg, tricyclic antidepressant)

Available Forms:

- Injection: 4% (0.48 mEq/mL), 4.2% (0.5 mEq/mL), 7.5% (0.89 mEq/mL), 8.4% (1 mEq/mL)
- Injection (premixed): 5% (0.6 mEq/mL)

Dose and Administration:

Metabolic Acidosis (severe), Hyperkalemia	
IV/IO	1 mEq/kg IV/IO *slow* bolus
Sodium Channel Blocker Overdose (eg, tricyclic antidepressant)	
IV/IO	1 to 2 mEq/kg IV/IO bolus until serum pH is >7.45 (7.50 to 7.55 for severe poisoning) followed by IV/IO infusion of 150 mEq $NaHCO_3$/L solution to maintain alkalosis

Action: Increases plasma bicarbonate, which buffers H^+ ion (reversing metabolic acidosis) forming carbon dioxide; elimination of carbon dioxide via the respiratory tract increases pH

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	wide (extracellular fluid)
Metabolism	combines with protons; taken up by cells
Excretion	urine, exhalation as CO_2
Half-life	unknown

Pharmacodynamics:

IV/IO

- Onset—rapid
- Peak—rapid
- Duration—unknown

Monitoring:

- Monitor SpO_2 and ECG continuously.
- Monitor ABG with attention to pH as appropriate.

Adverse Effects:

CNS	irritability, headache, confusion, stimulation, tremors, hyperreflexia, tetany, seizures, weakness
RESP	respiratory depression, apnea
CV	arrhythmia, hypotension, cardiac arrest
GI	abdominal distention, paralytic ileus
GU	calculi
SKIN	cyanosis, edema, sclerosis/necrosis (infiltration), vasodilation
ELECT	hypernatremia, hyperosmolarity
MISC	metabolic alkalosis, weight gain, water retention

Precautions:

- Ensure adequate ventilation because buffering action produces CO_2, which crosses blood-brain barrier and cell membranes more rapidly than (HCO_3^-). If ventilation is inadequate, increased CO_2 may result in transient paradoxical CSF and intracellular acidosis.
- Drug may inactivate catecholamines.
- When combined with calcium salts, precipitates into insoluble calcium carbonate crystals that may obstruct the IV catheter or tubing.

Special Considerations:

- Drug should not be administered via the endotracheal route.
- Irrigate IV/IO tubing with NS before and after infusions.

Sodium Nitroprusside

Classification: Vasodilator, antihypertensive

Indications:

- Cardiogenic shock (ie, associated with high SVR)
- Hypertension (severe)

Available Forms: Injection: 50 mg

Dose and Administration:

Cardiogenic Shock (high SVR), Hypertension (severe)		
IV/IO	<40 kg	1 to 8 µg/kg per minute IV/IO infusion
	>40 kg	0.1 to 5 µg/kg per minute IV/IO infusion

Action: Relaxes tone in all vascular beds (arteriolar and venous) through release of nitric oxide. This vasodilation results in reduced cardiac filling pressures and right and left ventricular afterload.

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	extracellular fluid
Metabolism	endothelial cells and RBCs (to cyanide), then liver (to thiocyanate)
Excretion	urine (thiocyanate)
Half-life	3 to 7 days (thiocyanate)

Pharmacodynamics:

IV/IO

- Onset—1 to 2 minutes
- Peak—Rapid
- Duration—1 to 10 minutes after stopping infusion

Monitoring:

- Monitor blood pressure and ECG continuously.
- Monitor thiocyanate (should be <50 mg/L) and cyanide (toxic is >2 µg/mL) levels in patients receiving prolonged infusion, particularly if rate is >2 µg/kg per minute or in patient with hepatic or renal dysfunction.

Adverse Effects:

CNS	seizures (thiocyanate toxicity), dizziness, headache, agitation, decreased reflexes, restlessness
CV	hypotension, bradycardia, tachycardia
GI	nausea/vomiting/abdominal cramps (thiocyanate toxicity)
ENDO	hypothyroidism
MISC	cyanide and thiocyanate toxicity

Precautions:

- Hypovolemia may worsen hypotensive effects of drug.
- Cyanide and thiocyanate toxicity may result if administered at high rates, for >48 hours, or to patients with decreased hepatic or renal function (drug is metabolized by endothelial cells to cyanide, then metabolized in the liver to thiocyanate).

Special Considerations:

- Drug is routinely mixed in D_5W. Drug may be administered into solutions containing saline.
- Use special administration tubing or wrap drug reservoir in aluminum foil or another opaque material to protect it from deterioration on exposure to light.
- Use solution immediately once prepared.
- Freshly prepared solution may have a very faint brownish tint without any change in drug potency.
- Drug may react with a variety of substances to form highly colored reaction products.

Terbutaline

Classification: Selective β_2-adrenergic agonist, bronchodilator
Indications: Asthma (status asthmaticus), hyperkalemia
Available Forms: Injection: 1 mg/mL
Dose and Administration:

Asthma (status asthmaticus), Hyperkalemia	
IV/IO	0.1 to 10 µg/kg per minute IV/IO infusion; consider 10 µg/kg load over 5 minutes
SQ	10 µg/kg SQ q 10 to 15 minutes until IV/IO infusion is initiated (maximum dose 0.4 mg)

Action: Stimulates β_2-adrenergic receptors

- Causes bronchodilation
- Causes vasodilation of arterioles
- Causes potassium to move intracellularly (will reduce serum potassium)

Pharmacokinetics:

Absorption	(not applicable with IV/IO route of administration)
Distribution	extracellular fluid
Metabolism	liver (partial)
Excretion	primarily unchanged in urine
Half-life	3 to 16 hours

Pharmacodynamics:

IV/IO

- Onset—rapid
- Peak—unknown
- Duration—2 to 6 hours

Monitoring: Monitor SpO_2, blood pressure, and ECG continuously.
Adverse Effects:

CNS	tremors, anxiety, headache, dizziness, stimulation
CV	palpitations, tachycardia, hypertension, hypotension, arrhythmias, myocardial ischemia
GI	nausea, vomiting

Special Considerations: Like other β_2-adrenergic agonists, terbutaline can lower potassium concentrations, which may be helpful therapeutically. The drug should be used cautiously in children with hypokalemia.