

Vasopressors and Inotropes

Definition and Epidemiology

Vasopressors and inotropes are critical medications used to restore hemodynamic stability in shock states by increasing vascular tone (vasopressors) or cardiac contractility (inotropes). They are mainstay therapies in ICU settings for conditions like septic, cardiogenic, and distributive shock.

- **Prevalence** Used in ~30-50% of ICU patients with shock; sepsis accounts for 60-70% of vasopressor use. Mortality in shock varies (20-50% in septic shock, 40-60% in cardiogenic shock).
- **Risk Factors** Sepsis, acute MI, hypovolemia, anaphylaxis, spinal cord injury.
- **Rare Demographics** Pediatric shock (e.g., meningococemia), pregnancy-related shock (e.g., amniotic fluid embolism), drug-induced (e.g., checkpoint inhibitors).

Pathophysiology

- **Mechanisms** Vasopressors (e.g., norepinephrine) act on α_1 -adrenergic receptors to induce vasoconstriction, increasing systemic vascular resistance (SVR) and mean arterial pressure (MAP). Inotropes (e.g., dobutamine) stimulate β_1 -adrenergic receptors, enhancing myocardial contractility and cardiac output (CO).
- **Effects** Vasopressors elevate MAP to maintain organ perfusion (target MAP ≥ 65 mmHg), while inotropes increase CO in low-output states (e.g., cardiogenic shock). Overuse risks ischemia or arrhythmias.
- **Molecular Pathways** Norepinephrine activates Gq-coupled α_1 receptors, increasing intracellular Ca^{2+} for smooth muscle contraction. Dobutamine enhances cAMP via β_1 receptors, boosting actin-myosin cross-bridging. Angiotensin II (ATII) acts on AT1 receptors, amplifying vasoconstriction.
- **Key Pathway** Receptor activation \rightarrow Second messenger signaling (Ca^{2+} , cAMP) \rightarrow Vasoconstriction or enhanced contractility \rightarrow Improved hemodynamics.

Causes

Category	Common Indications	Rare Indications	Notes
Septic Shock	Severe sepsis, bacterial infections	Fungal, viral sepsis	Sepsis: Most common; lactate >2 mmol/L guides therapy
Cardiogenic Shock	Acute MI, cardiomyopathy	Myocarditis, Takotsubo	Low CO (CI <2.2 L/min/m ²) drives inotrope use

Category	Common Indications	Rare Indications	Notes
Distributive Shock	Anaphylaxis, adrenal crisis	Neurogenic shock, checkpoint inhibitor toxicity	Low SVR; spinal shock has bradycardia
Hypovolemic Shock	Hemorrhage, dehydration	Amniotic fluid embolism	Vasopressors as adjunct after fluid resuscitation
Obstructive Shock	Massive PE, tamponade	Tension pneumothorax	Address underlying obstruction first
Drug-Induced	Beta-blocker overdose	Calcium channel blocker toxicity	Glucagon or high-dose insulin as adjuncts

Clinical Presentation

Symptoms

- Hypotension (SBP <90 mmHg or MAP <65 mmHg)
- Tachycardia (HR >100 bpm, compensatory) or bradycardia (neurogenic)
- Altered mental status, oliguria (<0.5 mL/kg/h)
- Rare Cool extremities (vasoconstriction), warm shock (early sepsis), cyanosis

Exam

- Cold, clammy skin (septic/cardiogenic shock) or warm, flushed skin (distributive)
- Weak pulses, delayed capillary refill (>2 sec)
- Cardiac S3 gallop (heart failure), jugular venous distension (JVD)
- Rare Paradoxical bradycardia (spinal shock), angioedema (anaphylaxis)
- Red Flags Lactate >4 mmol/L, ScvO₂ <70%, cardiac index (CI) <2.2 L/min/m²

Labs and Studies

Labs

- Lactate >2 mmol/L indicates tissue hypoperfusion; clearance predicts survival
- CMP Cr >1.5 mg/dL (renal hypoperfusion), K⁺ (arrhythmia risk)
- CBC Leukocytosis (sepsis), anemia (hemorrhage)
- Advanced Procalcitonin (sepsis), BNP (cardiogenic), cortisol (adrenal crisis)

Imaging

- Echocardiogram Assess LV/RV function, CO; guides inotrope choice
- CXR Pulmonary edema (cardiogenic), ARDS (sepsis)

- CT Angiography Rule out PE, aortic dissection
- Advanced Swan-Ganz catheter Measures CI, SVR, PCWP; less common with echo

Other

- EKG Arrhythmias, STEMI (cardiogenic shock)
- Central Venous O₂ Saturation (ScvO₂) <70% suggests low CO
- Advanced Near-infrared spectroscopy (tissue oxygenation), microcirculatory imaging (research)

Diagnosis

- Criteria Shock defined as hypotension (MAP <65 mmHg) with signs of organ hypoperfusion (lactate >2, oliguria, AMS) despite fluid resuscitation (30 mL/kg crystalloid).
- Differential Cardiogenic (low CO, high SVR), septic (high CO, low SVR), distributive (low SVR), hypovolemic (low preload), obstructive (mechanical).

Flowsheet

- Step 1 Stabilize ABCs Hypoxia → O₂; hypotension → Fluid bolus (NS 500 mL)
- Step 2 History/Exam Identify shock type (skin temp, JVD, lung exam)
- Step 3 Labs Lactate, ScvO₂, BNP; rule out infection (cultures), MI (troponin)
- Step 4 Studies Echo (CO, EF), EKG, CXR; Swan-Ganz if unclear etiology
- Step 5 Classify Shock Initiate vasopressor (septic, distributive) or inotrope (cardiogenic)

Treatment

General Principles Restore MAP (≥65 mmHg), optimize CO, and treat underlying cause (e.g., antibiotics for sepsis, PCI for MI).

Supportive Care

- Fluids NS/LR 30 mL/kg bolus; avoid over-resuscitation (↑ PCWP)
- Ventilation BiPAP/intubation for respiratory failure
- Monitoring Arterial line (real-time BP), CVP, urine output q1h

Specific Therapies

- Norepinephrine (NE) 5-20 mcg/min IV, first-line for septic/distributive shock (α₁, β₁)

- Vasopressin 0.01-0.04 units/min IV, adjunct in refractory septic shock (V1 receptor)
- Epinephrine 5-20 mcg/min IV, for anaphylaxis or cardiac arrest (α_1 , β_1 , β_2)
- Dobutamine 2-20 mcg/kg/min IV, for cardiogenic shock (β_1 , \uparrow CO)
- Milrinone 0.375-0.75 mcg/kg/min IV, for cardiogenic shock with high SVR (PDE3 inhibitor)
- Advanced Angiotensin II 10-40 ng/kg/min IV (refractory vasodilatory shock), levosimendan (Ca^{2+} sensitizer, research)
- Rare Indications Glucagon 5 mg IV (beta-blocker overdose), methylene blue (vasoplegic syndrome)
- Mechanical Support Intra-aortic balloon pump (IABP), ECMO for refractory cardiogenic shock

Monitoring

- Lactate clearance q2-4h (goal $>10\%/h$)
- Echo q12-24h to assess CO, EF
- Daily CMP, monitor for ischemia (EKG, extremities)

Complications

Acute

- Arrhythmias Tachyarrhythmias (epinephrine), VT (milrinone)
- Tissue Ischemia Digital necrosis, mesenteric ischemia (high-dose NE)
- Metabolic Acidosis Hyperglycemia (epinephrine), lactic acidosis

Long-Term

- Renal Failure AKI from hypoperfusion (20-30% of septic shock)
- Post-ICU Weakness Prolonged vasopressor use, steroid myopathy
- Rare Catecholamine cardiomyopathy (Takotsubo-like), vasopressor extravasation necrosis

Clinical Scenarios

Case 1 Septic Shock

- **Presentation** 70 y/o M with fever, confusion, and hypotension after pneumonia. Vitals BP 80/50, HR 120, SpO2 90%, RR 28. Exam Warm skin, bounding pulses.
- **Labs/Studies** Lactate 5 mmol/L, WBC 18K, ScvO2 65%. Echo Normal EF.
- **Interpretation** Septic shock, distributive (low SVR).

- **Management** NE 10 mcg/min IV, vasopressin 0.03 units/min, ceftriaxone 2 g IV. Fluids 30 mL/kg NS. ICU monitoring. Lactate clears to 2 mmol/L by 12h.

Case 2 Cardiogenic Shock

- **Presentation** 60 y/o F post-MI with dyspnea, hypotension. Vitals BP 85/55, HR 100, SpO2 88%, RR 24. Exam JVD, pulmonary edema.
- **Labs/Studies** BNP 1200 pg/mL, troponin 10 ng/mL, CI 1.8 L/min/m². Echo EF 25%.
- **Interpretation** Cardiogenic shock, low CO.
- **Management** Dobutamine 5 mcg/kg/min IV, furosemide 40 mg IV, PCI consult. IABP considered. MAP improves to 70 mmHg by 6h.

Case 3 Neurogenic Shock (Rare)

- **Presentation** 45 y/o M post-C5 spinal injury, hypotensive, bradycardic. Vitals BP 70/40, HR 50, SpO2 94%, RR 16. Exam Flaccid limbs, warm skin.
- **Labs/Studies** Lactate 3 mmol/L, normal EKG. CT spine C5 fracture.
- **Interpretation** Neurogenic shock, loss of sympathetic tone.
- **Management** NE 5 mcg/min IV, atropine 0.5 mg IV for bradycardia, methylprednisolone (spinal protocol). Neurosurgery consult. MAP stabilizes to 65 mmHg.

Expert Tips

- Use NE as first-line for septic shock; add vasopressin early (within 6h) if escalating doses
- Echo is critical to guide inotropes; dobutamine for low EF, milrinone for high SVR
- Avoid epinephrine in septic shock unless refractory; high arrhythmia risk
- Monitor digital perfusion hourly on high-dose vasopressors; use nitroglycerin paste for extravasation
- Consider angiotensin II in vasoplegic shock post-cardiac surgery; monitor for thrombosis
- Pitfall Over-resuscitation with fluids worsens cardiogenic shock; use echo to assess preload
- Advanced Microcirculatory imaging (e.g., sidestream dark field) predicts vasopressor response; levosimendan for RV failure

Key Pearls

- MAP \geq 65 mmHg is primary goal; lactate clearance is prognostic
- NE is first-line for septic/distributive shock; dobutamine for cardiogenic

- Echo guides therapy; low CI (<2.2) needs inotropes, high SVR needs vasodilators
- Monitor for ischemia (digits, gut) on high-dose vasopressors
- Rare causes like neurogenic shock require tailored therapy (e.g., atropine)

References

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