

Shock, Damage Control Resuscitation, and Vascular Access

Introduction

The goal of resuscitation is to maintain adequate perfusion. Resuscitation of the wounded combatant remains a formidable challenge on the battlefield. Resuscitation begins with the placement of two large-bore IVs (16 or 18 G). **The vast majority of casualties do not need any IV fluid resuscitation prior to arrival at a forward medical treatment facility.** For the more seriously injured trauma patients in the presurgical setting, the goal is to deliver the patient to a surgical facility expeditiously while maximizing the patient's chances of survival. This is accomplished using damage control resuscitation (DCR) principles at point of injury (POI), Role 1, and Role 2 facilities in order to mitigate the lethal triad of acidosis, hypothermia, and coagulopathy. For the approximately 10% of casualties who constitute the most seriously injured, are in shock and coagulopathic, and represent potentially preventable hemorrhagic deaths, blood products should be part of the initial fluid resuscitation.

This chapter will briefly address shock (including recognition, classification, treatment, definition, and basic pathophysiology), review initial and sustained fluid resuscitation, summarize currently available fluids for resuscitation, and describe vascular access techniques.

Recognition and Classification of Shock

Shock is a clinical condition marked by inadequate organ perfusion and tissue oxygenation, manifested by poor skin turgor, pallor, cool extremities, capillary refill greater than 2 seconds, anxiety/confusion/obtundation, tachycardia, weak or thready pulse, and hypotension. Lab findings include base deficit >5 and lactic acidosis >2 mmol/L.

- **Hypovolemic shock:** Diminished volume resulting in poor perfusion as a result of hemorrhage, diarrhea, dehydration, and burns. **Shock in the setting of trauma is hypovolemic until proven otherwise** (Table 7-1). In the prehospital setting, particularly at POI where laboratory analysis is not available, hypovolemic shock is indicated by altered mental status and a weak thready radial pulse.

Hypotension suggests a profound shock state, occurring after 30%–40% blood volume loss. Earlier signs are tachycardia, decreased pulse pressure, and mental status changes. However, even these earlier signs may not be readily apparent in military casualties who generally have a greater propensity for physiological compensation secondary to physical conditioning.

Table 7-1. Clinical Correlates in Hypovolemic Shock

Size Designation: Blood Loss (mL):	Class I <750	Class II 750–1,500	Class III 1,500–2,000	Class IV >2,000
Blood volume*	<15%	15%–30%	30%–40%	>40%
Pulse	<100	>100	>120	>140
BP	Normal	Normal	↓	↓
Pulse pressure	Normal	↓	↓	↓
RR	14–20	20–30	30–40	>35
UOP (cc/h)	>30	20–30	5–15	Negligible
CNS	Normal	Anxious	Confused	Lethargic

BP: blood pressure; CNS: central nervous system; RR: respiratory rate; UOP: urine output.

*Blood volume is approximately 7% (eg, a 70-kg patient has a blood volume of 4,900 mL).

- **Cardiogenic shock:** Pump failure from intrinsic cardiac failure or obstructive cardiac dysfunction from a tension pneumothorax (unilateral absence of breath sounds + distended neck veins) or cardiac tamponade (distended neck veins).
- **Distributive shock:** Poor perfusion due to loss of vascular tone.

- **Neurogenic shock:** Bradycardia with hypotension, seen with spinal cord injury T6 and above due to loss of sympathetic tone and unopposed parasympathetic stimulation with resultant vasodilation.
- **Septic shock:** Fever, hypotension, tachycardia, and warm extremities from massive vasodilation related to infection.

Treatment of Hypovolemic Shock—Control Bleeding!

The goal in the treatment of shock is to restore tissue perfusion and oxygen delivery (dependent on hemoglobin, cardiac output, and oxygenation).

- Control obvious bleeding and assess for occult hemorrhage.
- Secure the airway and administer oxygen for $\text{SaO}_2 < 92\%$.
- Diagnose and treat tension pneumothorax.
- Assess circulation and establish IV access.
 - Consider cardiac tamponade, even if there are no distended neck veins.
- Presurgical setting: follow TCCC guidelines (permissive hypotension in the non-head injured patient, Hextend bolus $\times 2$).
- Role 2/3: Resuscitate initially with any fluid available. If patient is received after prior treatment, consider fluids already received in treatment decisions. Strong consideration must be given for early blood product transfusion, particularly in those casualties at risk for a massive transfusion (>10 units of PRBCs [packed red blood cells] in 24 hours).
 - Physiological/laboratory predictors of massive transfusion include:
 - ◆ Systolic blood pressure <110 .
 - ◆ Heart rate >105 .
 - ◆ Hematocrit $<32\%$.
 - ◆ pH <7.25 .
 - ◆ 3 of 4 risk factors = 70% risk massive transfusion.
 - ◆ 4 of 4 risk factors = 85% risk massive transfusion.
 - Injury patterns associated for risk of massive transfusion include:
 - ◆ Truncal/axillary/neck/groin bleeding not controlled by tourniquet or hemostatic dressings.
 - ◆ Multiple amputations.

- ◆ Large soft-tissue injuries with uncontrolled bleeding.
- ◆ Large hemothorax.
- ◆ Large hemoperitoneum.

These patients should be immediately resuscitated with blood products (PRBCs: fresh frozen plasma [FFP]:platelets) in a 1:1:1 ratio or consider fresh whole blood if full component therapy not available.

- Based on response to fluids, casualties will fall into three groups: responders, transients, and nonresponders.
 - **Responders:** Casualties with a sustained response to fluids may have had significant blood loss, but have stopped bleeding. However, they may still require definitive surgery.
 - **Transient** and **nonresponders** are continuing to bleed. They need immediate surgical intervention.
 - ◆ Start blood product transfusion as soon as possible, with a target goal ratio of 1:1:1 (PRBCs:FFP:platelets).
 - ◆ For nonresponders, fluids may be given to keep the casualty alive, but you should not attempt to restore pressure to normal. Consideration should be taken into account of the futility of the resuscitation, depending on the tactical scenario.
 - ◆ Follow **controlled resuscitation** guidelines as presented in this chapter.

Exsanguinating hemorrhage is the cause of most preventable deaths during war. Combat casualties in shock should be assumed to have hemorrhagic shock until proven otherwise.

- Vasopressors have NO role in the initial treatment of hemorrhagic shock.
- Resuscitation fluid selection.
 - See TCCC guidelines for the most current management (Table 7-2).
 - Blood product transfusions should be considered early in the resuscitation, particularly in patients who have lost 30% or more of their blood volume. Blood products may also be

Table 7-2. Intravascular Resuscitation Fluids

Fluid/Initial Dose	Indication	Advantages	Cautions
Crystalloids			
Saline	Hypovolemia, hemorrhage, shock, burns	Easy to store, inexpensive, proven effectiveness, isotonic	Weight ratio—requires 3:1 for lost blood, dilution, edema, coagulopathy
Ringer's lactate			
Hypertonic saline	Hemorrhagic shock: 4 cc/kg or 250 cc bolus, may repeat once	Lighter weight	>500 cc—risk of hypernatremia, seizures
3%–5%		Small volume = large effect	Do not use for dehydration from vomiting, diarrhea or sweating, or heat injuries
7.5%*	Burns—only one dose initially	Increased cardiac contractility	Do not repeat without addition of other fluids
HTS—colloid combinations*		Longer duration of effect than plain HTS?	Must replace depleted extravascular fluid
HTS dextran*			
HTS Hetastarch*			
Colloids			
Albumin	Hemorrhagic shock (500–1,000 mL bolus)	Longer duration	Overuse may lead to “leak” into tissue
Artificial colloids	Burns? 3rd day	1:1 replacement for blood	Binds immunoglobulins and Ca ²⁺
Dextran		Raises plasma oncotic pressure	Must replace depleted extravascular fluid
6% Hetastarch (Hextend, Hespan)		Recruits extravascular fluid	Artificial colloids:
10% Pentastarch*		Weight/cube better than crystalloids	coagulopathy, allergic reaction, osmotic diuresis, interferes with cross-matching
Gelatin-based colloids*			Hetastarch: 1 fibrinolysis, 1 amy/lase
Oral rehydration fluids			Maximum dose: 20 mL/kg/d (about 1.5 L)
	Dehydration-controlled hemorrhage	Fluids of opportunity	Austere option in abdominal wounds and unconscious patients, but use with caution
Blood			
	Burns	Nonsterile ingredients: 4 tpsps sugar, 1 tsp salt, 1 L water	
	Hemorrhage—type O universal donor	Carries oxygen	Storage, type, and cross-match
		Autotransfusion	Transfusion reactions, infection, immunogenic
	Hemorrhage	Walking blood bank	
Artificial blood			
Hemoglobin-based		Easy storage	Experimental only, not yet available for use
Fluorocarbon-based		No type and cross-matching	Fluorocarbons require supplemental oxygen
			Future option?

FDA: Food and Drug Administration; HTS: hypertonic saline. *Not FDA approved.

Data source: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

necessary in patients who have not reached this threshold, but who have ongoing blood loss or who are at high risk of ongoing bleeding. Fresh whole blood therapy should be considered at levels of care where component blood product therapy (ie, PRBCs, FFP, platelets) is inadequate to meet the target goal ratio of 1:1:1.

Concept of Controlled Hypotensive Resuscitation / Permissive Hypotension

- Raising the blood pressure with fluid resuscitation may dislodge established clots, leading to continued blood loss. Prior to establishing definitive hemorrhage control, use controlled resuscitation to achieve and maintain adequate perfusion as demonstrated by at least one of the following prioritized goals:
 - Regains consciousness (follows commands).
 - Palpable radial pulse.
 - SBP (systolic blood pressure) ~90 mm Hg.
 - MAP (mean arterial pressure) ~60 mm Hg.

Controlled resuscitation (permissive hypotension) is NOT a substitute for definitive surgical control. It is an attempt to keep a critically injured casualty alive until definitive treatment.

- Endpoints of resuscitation.
 - Following definitive hemorrhage control, more traditional endpoints of resuscitation include:
 - ◆ Blood pressure: SBP >110–120 mm Hg, MAP >65–70 mm Hg.
 - ◆ Urine output: >0.5 mL/kg/h (approximately 30 mL/h).
 - ◆ Correction of acidosis by achieving base deficit <2 or serum lactate <2 mmol/L.
 - Hypothermia: It is important to maintain normal body temperature. Fluids, blood products, and casualty care areas must be warmed. Casualties frequently arrive at the facility hypothermic. Keep casualties covered when on litters, radiograph tables, and operating tables. External warmers should be used in all casualty care areas from

initial emergency area through operating room and ICU. Hypothermia is much easier to prevent than it is to treat. See further discussion of hypothermia in Chapter 12, Damage Control Surgery. Also see JTTS (Joint Theater Trauma System) Clinical Practice Guideline “Hypothermia Prevention.”

Vascular Access

- Vascular access is a critical early step in the management of trauma.
- Large-bore peripheral access in the antecubital fossa should be attempted first; if unsuccessful, consider intraosseous (IO) device placement for initial resuscitation, followed by alternatives such as percutaneous central line (ie, subclavian, internal jugular, femoral veins) or “cutdowns” (saphenous vein either at the groin or ankle).

Subclavian Vein Access or Internal Jugular Venipuncture

- Place the casualty supine in the Trendelenburg position (15° head down).
- Prep and drape subclavian/jugular area. Sterile gloves must be worn. Use central line access kit.
 - Subclavian line.
 - ◆ With an index finger placed at the sternal notch, the thumb is placed at the junction of the medial and middle third of the clavicle.
 - ◆ 1% lidocaine is infiltrated into the skin, subcutaneous tissue, and periosteum of the clavicle.
 - ◆ Introduce a large caliber needle with an attached 5-mL syringe at the junction of the middle to lateral portion of the clavicle. Insert with the bevel of the needle up, directing the needle toward the contralateral clavicular head. Keep the needle horizontal to avoid a pneumothorax.
 - ◆ While aspirating, slowly advance the needle underneath the clavicle.
 - Jugular vein line.
 - ◆ Turn the casualty’s head 45° toward the contralateral side to expose the neck. Position must be altered to neutral position if concern exists for cervical spine injury.

- Current standard of care is to perform under ultrasound guidance; however, if not available, it can be performed using landmarks as follows:
 - ◆ Identify the apex of the anterior cervical triangle formed by the heads of the sternocleidomastoid muscle to locate the carotid artery.
 - ◆ Palpate the carotid artery and stay lateral with your venipuncture.
 - ◆ Introduce a large-bore needle on a 10-mL syringe at a 45° angle into the apex of the triangle, lateral to the carotid pulse.
 - ◆ Advance the needle caudally, parallel to the sagittal plane and at a 30° posterior angle (ie, toward the ipsilateral nipple).
 - ◆ When free flow of venous blood appears, advance the needle an additional 4 mm (the length of the needle bevel), then remove the syringe and quickly cover the hub of the needle to prevent air embolism.
 - ◇ If air or arterial blood appears, stop immediately. Withdraw needle immediately and place pressure at the site for at least 5 minutes.
 - ◆ If no venous blood returns after advancing 5 cm, slowly withdraw the needle while aspirating. If this fails, redirect the needle.
- Subclavian vein or internal jugular vein catheter insertion.
 - ◆ Once the needle is in the vein, introduce the “J” wire through the needle (Seldinger technique). The wire should pass with minimal resistance. If the wire does not pass easily, withdraw the entire apparatus and reattempt line placement.
 - ◆ Remove the needle.
 - ◆ Enlarge the puncture site with a scalpel and dilator.
 - ◆ Pass the catheter over the wire while holding the wire in place to a depth of 18 cm on the left and 15 cm on the right for subclavian, and to a depth of 9 cm on the right and 12 cm on the left for jugular vein; then remove the wire.
 - ◆ Aspirate from all ports, flush all ports, suture in place, apply antibiotic ointment, dress area, secure tubing, and label date of insertion.

- ◆ Chest radiograph to ensure line position and rule out pneumothorax.

Intraosseous Infusion

- Contraindications.
 - Trauma or infection at insertion site.
 - Excessive tissue or absence/inadequate anatomic landmarks.
 - Recent IO device at the same site.
 - Fracture of insertion bone.
 - Recent sternotomy.
- Devices/procedure.
 - Procedure techniques vary based on model and can be either manual or power-driven.
 - ◆ Manual: Cook, FAST1, sternal EZ-IO, Sur-Fast.
 - ◆ Semiautomatic: Adult and pediatric Bone Injection Gun (B.I.G.)—spring-loaded, adult and pediatric EZ-IO—battery-powered drill.
 - ◆ Adult versus pediatric IO devices and needles are usually specified on the packaging labeling. Pediatric IO devices are only approved for the proximal and distal tibia.
 - Insertion location.
 - ◆ Tibia: B.I.G., Cook, Sur-Fast, EZ-IO.
 - ◆ Proximal humerus: EZ-IO.
 - ◆ Sternum (manubrium): FAST1, sternal EZ-IO.

**DO NOT USE HUMERAL OR TIBIAL IO DEVICES
ON THE STERNUM.**

- All IV fluids (except hypertonic saline [HTS]) and medications can be administered via IO in similar rates to IV infusions.
- Confirm placement of IO by aspirating a small amount of blood and then flush with 10 mL of normal saline.

IO device placement is age and anatomical location specific. Care must be taken to ensure IO device insertion is correlated to the packaging labeling instructions (eg, tibial IO cannot be used on the sternum because of the length of the needle).

- The IO device should be removed as soon as possible after other IV access is established, but definitely before 24 hours.
- **See JTTS Clinical Practice Guideline “Damage Control Resuscitation.”**
- Types of IV fluids.
 - ◆ Lactated Ringer (LR) solution: 1,000 mL expands intravascular volume by only ~250 mL within 1 hour after infusion. Normal saline should be discouraged.
 - ◆ Hextend (500 mL, Hetastarch 6% + a physiological balanced crystalloid carrier, including lactate buffer and glucose) expands intravascular volume by ~800 mL in 1 hour, is functionally equivalent to three bags of LR, and is sustained for at least 8 hours. May repeat once for a total of 1,000 mL.
 - ◆ HTS 7.5% results in the same physiological response with one-eighth the volume of LR or saline. Two infusions of 250 mL can be used. Although this recommendation has been made by the Institute of Medicine (in Washington, DC) and two military consensus groups, HTS 7.5% is not commercially available. HTS 3% and HTS 5% can be used instead and are formulary stock items.

Caution: Hextend and HTS are effective primarily by shifting extracellular volume into intravascular space. They may be less effective if administered in casualties with significant dehydration and require supplementation with judicious use of crystalloid.

- Isolated neurogenic shock.
 - ◆ Intravascular resuscitation with crystalloid to maintain systolic mean arterial pressure >90 mm Hg or SBP >110.
 - ◇ Crystalloid fluid resuscitation is first line treatment in isolated neurogenic shock.
- Add a vasopressor after appropriate intravascular volume challenge (generally 2–3 L) to address the loss in vascular tone. The type of vasopressor chosen should be based on availability.
- Septic shock.
 - ◆ Initial resuscitation (first 12 hours).

- ◇ Targets:
 - Mean arterial pressure ≥ 65 mm Hg or SBP ≥ 90 .
 - Central venous pressure 8–12 mm Hg.
 - Urine output ≥ 0.5 mL/kg/h.
 - Central venous or mixed venous oxygen saturation $\geq 70\%$.
- ◇ Begin intravenous broad-spectrum coverage within the first hour of recognition of severe sepsis.
- ◇ Add a vasopressor after appropriate intravascular volume challenge (generally up to 5 L crystalloid and/or colloid).
 - Norepinephrine, initial dose 8–12 $\mu\text{g}/\text{min}$, then titrate to effect at 2–4 $\mu\text{g}/\text{min}$. (In a septic patient, use the following formula [weight-based dosing]: 0.01–3 $\mu\text{g}/\text{kg}/\text{min}$ [could be as much as 0.7–210 $\mu\text{g}/\text{min}$ in 70-kg patient].)
 - Vasopressin 0.04 units/min (may titrate down for effect; do not titrate above maximum: 0.04 units/min).
- ◇ Institute early acute lung injury/acute respiratory distress syndrome mechanical ventilation measures with low tidal volumes (4–6 mL/kg lean body mass) and end-inspiratory plateau pressures < 30 cm H₂O.
- Subsequent therapy.
 - ◆ Overall fluid balance target after 12 hours of resuscitation is between 3–12 L. More than 12 L positive balance associated with increased mortality.
 - ◆ Consider blood transfusion if hemoglobin < 7 to target hemoglobin of 7.0–9.0 g/dL.

**For Clinical Practice Guidelines, go to
http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs**