



## Chapter 6 – Shock

**NOTE: CONTENT CONTAINED IN THIS DOCUMENT IS TAKEN FROM ROSEN'S EMERGENCY MEDICINE 9th Ed.**

*Italicized text is quoted directly from Rosen's.*

### Key Concepts:

1. *Circulatory shock can occur with normal arterial blood pressure, and not all patients with arterial hypotension have circulatory shock.*
2. *A base deficit more negative than -4mEq/L or a serum lactate >4.0 mmol/L warrants a presumptive diagnosis of shock.*
3. *Urine output is a reliable index of vital organ perfusion in patients with suspected shock. Normal urine output is 1.0 ml/kg/h. Output less than 0.5 ml/kg/hr indicates severe renal hypoperfusion.*
4. *A combination of worsening base deficit, increasing serum lactate, and low urine output represent persistent or worsening circulatory shock.*
5. *Early initiation of fluid resuscitation, with pressor support if needed, and appropriate antimicrobial therapy improve the outcomes in patients with septic shock.*
6. *The use of defined physiologic endpoints to measure systemic perfusion during resuscitation (quantitative resuscitation) improves outcomes for ED patients with shock.*

### Core Questions:

1. What are the four categories of shock? Is there a more clinically relevant method of categorizing shock? (Box 6.1)
2. What is base deficit and what does its measurement mean?
3. Describe the first and second phase of organ injury secondary to hemorrhagic shock.
4. What are the three major points of dysfunction that contribute to septic shock?
5. What is neurogenic shock, and how does it differ from spinal shock?
6. What are the empirical criteria for the diagnosis of circulatory shock? (Box 6.2)
7. What variables indicate tissue hypoperfusion? (Box 6.4)
8. What is permissive hypotension and when should it be considered?
9. What is early goal-directed therapy? Is this strategy still recommended?
10. Describe the adrenergic effects of the following vasopressors and inotropes:
  1. Phenylephrine
  2. Norepinephrine
  3. Dopamine
  4. Epinephrine
  5. Dobutamine
  6. Ephedrine



## Wisecracks:

1. What is lactate clearance, and how is it measured?
2. How much fluid should a septic patient receive before pressor therapy is initiated?
3. What is the 1:1:1 transfusion rule, and when is it used?
4. What percentage of the myocardium must be dysfunctional to cause cardiogenic shock?

## Rosen's in Perspective

As you can probably guess, this introductory chapter is exceedingly important for practitioners of emergency medicine. Chapter 6 in Rosen's 9th Edition contains core knowledge that anyone working in acute care must have a mastery of. If you ever even plan to walk through an ED, you need to put what you are doing aside and focus for the next 30-45 minutes.

Shock, in its many forms, represents the danger zone, so knowing how to correctly identify what is causing this patient's life threatening pathophysiologic demise is tantamount. Today, we will give you an organized approach that will allow you to classify shock into four categories. Additionally, we will give you a broad sense of the treatment for each subclassification of shock and detail some physiologic endpoints that will help guide continuing therapy. While this is not the longest chapter we have or will present on, the information in this podcast is FUNDAMENTAL. Know this content cold (or warm...you will get the joke later).

## Core Questions:

**[1] What are the four categories of shock? Is there a more clinically relevant method of categorizing shock? (Box 6.1)**

### Four Categories of Shock

1. Cardiogenic
2. Hypovolemic
3. Obstructive
4. Distributive



**Table 6.1** - Five categories of shock according to primary treatment of causes and problems.

Treatment Modality	Cause of Shock
Infusion of volume	<ul style="list-style-type: none"> <li>• Hemorrhagic shock - (trauma, GIB, etc.)</li> <li>• Hypovolemia - GI losses, dehydration, third space sequestration from inflammation.</li> </ul>
Volume infusion & Vasopressors	<ul style="list-style-type: none"> <li>• Septic Shock</li> <li>• Anaphylactic Shock</li> <li>• Neurogenic Shock</li> <li>• Toxidromes - various overdoses</li> </ul>
Improve pump function (inotropic support, or reverse cause of pump dysfunction)	<ul style="list-style-type: none"> <li>• Myocardial ischemia</li> <li>• Cardiomyopathy                             <ul style="list-style-type: none"> <li>○ Myocarditis vs. Chronic causes of myocardial dysfunction - ischemia, DM, infiltrative, etc.</li> </ul> </li> <li>• Cardiac arrhythmias</li> <li>• Septic shock with resultant cardiac dysfunction - hypodynamic shock</li> <li>• Overdose of negative inotrope (Beta blockers etc.)</li> <li>• Structural heart damage                             <ul style="list-style-type: none"> <li>○ Trauma, septal rupture, papillary muscle rupture</li> </ul> </li> </ul>
Relieve obstruction	<ul style="list-style-type: none"> <li>• PE</li> <li>• Tamponade</li> <li>• Tension PTX</li> <li>• Valvular dysfunction (thrombosis of prosthetic valve, valvular stenosis, etc.)</li> <li>• congenital heart disease</li> <li>• HOCM (or “critical idiopathic sub-aortic stenosis”)</li> </ul>
Antidotes to cellular or mitochondrial poisons	<ul style="list-style-type: none"> <li>• CO, Methemoglobinemia, H<sub>2</sub>S, Cyanide</li> </ul>

This is a bit of an awkward table... I typically build my differential around 4 categories and use the clinical history and exam to narrow from there. There is arguably a role for POCUS in the hypotensive patient (with various protocols that can be used), however that is beyond the scope of the chapter.



## [2] What is base deficit and what does its measurement mean?

Base deficit is defined as the quantification of the amount of strong base that would be needed to be added to one litre of blood to normalize its pH.

Largely, base deficit is a rough metric of how well the body is perfusing its tissues. As the body's vital organs begin to receive less and less substrate, anaerobic respiration begins. As such, increasing lactic acid and other substrates of anaerobic respiration begin to accumulate. The more the body dips into its reserve to buffer and maintain a normal pH, the lower the base deficit value trends.

Normally, the base deficit is  $> -2$  mEq/L. A base deficit of less than or equal to 4 mEq/L is one of the empirical criteria for the diagnosis of circulatory shock (discussed in question 6).

## [3] Describe the first and second phase of organ injury secondary to hemorrhagic shock.

**Hemorrhagic Shock = rapid reduction of intravascular blood volume**

- *First phase:* Blood flow is initially directed away from noncritical organs/tissues, causing a shift toward anaerobic metabolism and production of lactic acid. This will happen before hypotension occurs, therefore acidemia precedes any major decrease in cardiac output (reflected by base deficit, as discussed in Q2). Hypotension occurs when cardiac output can no longer support the blood pressure. This results in reduced end organ perfusion and further activation of the inflammatory cascade.
- *Second phase:* Occurs during **resuscitation**. Resuscitation releases inflammatory mediators produced during the first phase back into circulation, inducing further organ injury. This leads to increased neutrophil activity and cytokine production, capillary leakage and acute respiratory distress syndrome (ARDS), as well as insults to kidney (preglomerular artery spasm and acute tubular necrosis), liver (centrilobar injury and elevated transaminases), and heart (cardiac ischemia secondary to supply-demand mismatch).

## [4] What are the three major points of dysfunction that contribute to septic shock?

**MAJOR KEY ALERT (props to DJ Khaled for the signpost pearl)**

As you may know, sepsis is a special beast. Although it was once held as the prototypical example of distributive shock, we now see it for what it is: a beautifully complicated and



infuriating MESS. There are numerous points of physiologic dysfunction that occur in the septic patient, but if you keep the following three key areas of demise in mind, you should be alright.

### 1. Relative/Absolute Hypovolemia

- a. Absolute hypovolemia - the patient becomes volume depleted from accelerated fluid loss via diaphoresis, tachypnea, GI losses, and decreased fluid intake during the development of illness
- b. Relative hypovolemia - the patient loses fluid from widespread vasodilation and increasing capillary leakage; this leads to diminished intravascular volume and worsening tissue perfusion

### 2. Systemic Inflammation

- a. This is perhaps most well-known point of dysfunction in the septic patient. Systemic inflammation contributes widespread organ dysfunction, and can lead to non-cardiogenic pulmonary edema (i.e., ARDS) from increasing capillary leak in the lungs.

### 3. Direct Myocardial Depression

- a. This point of dysfunction was one that was traditionally overlooked; however, it is exceedingly important to consider. Essentially, the increased production and release of inflammatory mediators (e.g., TNF-alpha, interleukin-1-beta) injure the myocardium, diminishing contractility. Other pathologic processes (overproduction of nitric oxide and impaired mitochondrial oxidative phosphorylation) are thought to further contribute to the process.

## [5] What is neurogenic shock, and how does it differ from spinal shock?

- **Neurogenic shock** = interrupted sympathetic and parasympathetic input from spinal cord to heart and vasculature. Classically - vasodilation and bradycardia (but can have a wide variation in heart rate depending on other factors).
- **Spinal shock** = loss of sensation and motor function following spinal cord injury. reflexes are depressed or absent distal to site of injury. This may last for hours to weeks post-injury. **The end of spinal shock is marked by the return of the bulbocavernosus reflex** (internal/external anal sphincter contraction in response to squeezing the glans penis or clitoris, or tugging on an indwelling foley). Never checked one of them before.



## **[6] What are the empirical criteria for the diagnosis of circulatory shock? (Box 6.2)**

**Why do we care:** ED patients presenting with shock often have no obvious cause. We need to key on key elements of the hx/exam to make a diagnosis and start appropriate management. Rosen's stresses that HR and BP values do not correlate well with cardiac index ( $=CO/BSA$  - body surface area) in shock due to a variety of factors, and can often underestimate the severity of hypoperfusion.

### **Box 6.2 - Empirical Criteria for Diagnosis of Circulatory Shock**

1. Ill appearance/altered mental status
2. Heart rate > 100/min
3. Respiratory rate > 20/min or PaCO<sub>2</sub> <32mmHg
4. Urine output < 0.5mL/kg/h
5. Arterial hypotension > 30 minutes (continuous)

## **[7] What variables indicate tissue hypoperfusion? (Box 6.4)**

Another list, folks.

Memory aid? Visualize an unwell patient, in a bed, with monitors and foley hooked up, and you will have several of these. Go head-to-toe down the patient, look at the monitors, and the foley bag, look at your bloodwork (ABG or VBG)... put yourself in the situation and I think you will have an easier time remembering this.

### **Box 6.4 - Variables indicating tissue hypoperfusion**

1. Hypotension
2. Tachycardia
3. Low cardiac output
4. Dusky or mottled skin
5. Delayed cap refill
6. Altered Mental Status
7. Low urine output
8. Low venous O<sub>2</sub> saturation
9. Elevated lactate level.

## **[8] What is permissive hypotension and when should it be considered?**

Nice summary post by Chris Nickson on LITFL [here](#).

Rosen's defines permissive hypotension as tolerating Mean Arterial Pressure (MAP) > 50mmHg to avoid unnecessary fluid resuscitation, which can worsen coagulopathy, hypothermia, and



may destabilize clots (don't pop the clot). This is still a controversial approach, mainly applicable to the penetrating trauma patient.

Notes:

- The approach is based on allowing SBP to fall low enough to avoid exsanguination, while maintaining perfusion.
- May theoretically reduce clot destabilization and re-bleeding.
- the goal is hemorrhage control - once this is achieved, then move to normal hemodynamic targets.

Caveats

- Not validated in setting of traumatic brain injury (i.e. we know hypotension and hypoxia is bad for injured brain), blunt trauma, or delayed presentations.
- Evidence overall is not high-level - mostly animal studies. A [prospective study](#) by Bickell et al. (1994) showed mortality benefit in 598 hypotensive patients with penetrating torso injury (70% vs. 62%, p=0.04)
- Check out the linked LITFL post for more references.

## [9] What is early goal-directed therapy? Is this strategy still recommended?

**EGDT** - initially introduced in this 2001 [study](#) by Rivers et al., compared use of EGDT to usual care in severe sepsis/septic shock and found a mortality benefit (30.5% vs. 46.5% p=0.009). Another solid LITFL summary post can be found [here](#).

EGDT [protocol](#) from the trial:

They measured 5 parameters:

1. Central Venous Pressure 8-12mmHg
2. Mean Arterial Pressure 65-90mmHg
3. Urine output >0.5ml/kg/hr
4. ScvO<sub>2</sub> >70% (central venous O<sub>2</sub> saturation)
5. Hematocrit > 30%

The protocol used these interventions:

1. Early mechanical ventilation
2. Fluid resuscitation
3. Use of vasopressors
4. Transfusion

The overall goal was to improve tissue O<sub>2</sub> delivery early on, based on observations of O<sub>2</sub> deficits in septic patients (high lactate and high ScvO<sub>2</sub>).

There have been some important trials - ARISE (Au), ProCESS (US), and ProMiSe (UK) published since. These are 3 government-funded, multi-centre RCTs that did not show a benefit of EGDT compared to usual care. A [meta-analysis](#) by the PRISM investigators in 2017 of these



3 trials showed no difference in mortality when compared to usual care. However, hospitalization costs were higher.

In summary - EGDT and all of its various parameters does not really have a place in modern sepsis care. The major pillars of sepsis care are:

1. Early fluid resuscitation (30mL/kg in most situations).
2. Support MAP with vasopressors if needed
3. Early broad spectrum antibiotics
4. Source Control
5. ±mechanical ventilation and intubation if indicated

**[10] Describe the adrenergic effects of the following vasopressors and inotropes:**

1. Phenylephrine
2. Norepinephrine
3. Dopamine
4. Epinephrine
5. Dobutamine
6. Ephedrine

Alright, guys. Strap in, because you are about to enter the most high-yield pimp prep session you could imagine.

Having a solid working knowledge of the adrenergic effects of each of the pressors and inotropes noted above will allow you to ace any midnight ICU/Anesthesia/ED Jeopardy extravaganza AND (perhaps more importantly) give you a nuanced approach to pressor selection when you encounter the shocky patient. There are a few infographics that can help you remember these pressor/inotrope mechanisms (one of which is listed below), but it usually helps if you are able to draw it out yourself. Take some time, listen to the podcast, and take notes.

Below, we have constructed a table for your reference. The bolded adrenergic receptor effect indicates the which receptor is affected most by pressor or inotrope action. Given dopamine's dose-dependent adrenergic effects, there are no bolded terms.

Check out the LITFL Vasopressor /Inotropes post here for more:

<https://lifeinthefastlane.com/cc/inotropes-vasopressors-and-other-vasoactive-agents/>





Medication	Alpha Adrenergic Effects	Beta Adrenergic Effects	Hemodynamic Effects
Phenylephrine	<b>Alpha 1</b> > Alpha 2	NO EFFECT	↑PVR ↓HR (reflex bradycardia)
Norepinephrine	<b>Alpha 1</b> >> Alpha 2	Beta 1 > Beta 2	↑PVR ↑CO
Epinephrine	Alpha 1 > Alpha 2	<b>Beta 1</b> > Beta 2	↑PVR ↑CO
Dopamine	Alpha 1 (>10 mcg/kg/min)	Beta 1, Beta 2 (5-10 mcg/kg/min)	5-10 mcg/kg/min - ↑CO >10 mcg/kg/min - ↑PVR
Dobutamine	Alpha 1 (minimal)	<b>Beta 1</b> > Beta 2	↓PVR ↑CO
Ephedrine	Alpha 1, Alpha 2 (minimal)	<b>Beta 1</b> > Beta 2	↑PVR ↑CO

**Wisecracks:**

**[1] What is lactate clearance, and how is it measured?**

**Lactate Clearance = ([Initial Lactate - Delayed Lactate]/ Initial Lactate) x 100**

For all of you math whizzes out there, this seems intuitive, but for the vast majority of us this may not be so simple. So, let's take a deep dive. This formula should seem familiar to you all. It is, simply, a percentage change equation. You are solely looking to see by what percentage the repeat lactate has changed in comparison to your initial lactate. Generally, we are looking to see a 10-20% diminishment in serum lactate 2 hours after beginning resuscitation. If you do not meet this goal, you need to consider other therapies that will improve organ perfusion.

Lactate clearance is a solid metric, and is as good as measuring central venous oxygen saturation. Generally speaking, you want to continue to resuscitate until lactate normalizes (<2 mM/L).

**[2] How much fluid should a septic patient receive before pressor therapy is initiated?**

Pretty simply here, guys. As per the 2018 update to the Surviving Sepsis Guidelines, if the patient is still hypotensive despite receiving 30 cc/kg of IV crystalloid, you can consider pressor



therapy. Of course, there will be individual variation based on practitioner and institutional preference, but this is the guideline recommendation. KNOW IT. LOVE IT.

### **[3] What is the 1:1:1 transfusion rule, and when is it used?**

The 1:1:1 transfusion rule speaks to the need to consider all blood products when resuscitating a patient with hemorrhagic shock. Simply put, if your patient has needed greater than 2 units of PRBC's, you should consider concomitantly transfusing platelets and fresh frozen plasma in a ratio of 1:1:1. You will see this integrated into many institution or health region-specific massive transfusion protocols, but you may find yourself in an area that does not have a formal plan detailed. Be sure to stress the importance of transfusing all of these blood products, as simply slamming PRBC's in may actually worsen outcomes and bring about disseminated intravascular coagulation (DIC).

Using the 1:1:1 ratio to guide your management has been shown to reduce rates of death due to exsanguination at 24 hours and leads to better hemostasis. So, just remember: blood is more than red blood cells. If you need lots, balance is key.

### **[4] What percentage of the myocardium must be dysfunctional to cause cardiogenic shock?**

As per Rosen's 9th Edition, cardiogenic shock typically comes about after greater than **40%** of the myocardium is compromised. Remember, this is not necessarily from an ischemic process (although, this is likely the most common cause we will see in the ED). You need to consider the effects of systemic inflammation (remember our discussion of sepsis in Q4), toxins, and immune injury in your differential.