**SHOCK: THE BASICS (AND A BIT MORE…)**

**Introduction**

Shock is a common clinical entity that requires a sophisticated understanding of normal and altered physiology, diagnosis, and management of critically ill patients. This module will discuss the classification and pathogenesis of the various forms of shock. The approach to diagnosis and management of a patient in shock will also be discussed. Although the discussion will include both cardiac and non-cardiac etiologies of shock, an emphasis will be placed on the forms of shock that are most likely to be encountered in the cardiac ICU.

**Definition and Epidemiology of Shock**

Shock can be broadly defined as the final common pathway of circulatory failure that results from any one of multiple etiologies and is the manifestation of insufficient cellular oxygen distribution and utilization.[[1]](#endnote--1),[[2]](#endnote-0) In other words, there are many different causes of shock, but ultimately shock is the circulatory failure that result in inadequate tissue oxygenation. It is important to remember that shock is characterized by the systemic manifestations of ischemia or hypoxia at the *cellular* level.

Circulatory shock is a common condition. One-third of patients in ICU settings exhibit some form of shock and the mortality rate is

In one large multi-center study of adults presenting with shock and vasopressor requirements, the prevalence of the different types of shock were: distributive (septic) 62%, distributive (non-septic) 4%, cardiogenic 16%, hypovolemic 16%, and obstructive 2%.[[3]](#endnote-1)

**Pathophysiology of Shock**

There are a variety of different ways to categorize the different types of shock. Although each type of shock is traditionally characterized by certain hemodynamic and molecular characteristics, there can be considerable overlap in the hemodynamic profiles and the clinical presentations between different forms of circulatory shock. Shock can be thought of in terms of hypodynamic and hyperdynamic states. A hypodynamic state is characterized by reduced cardiac index, increased systemic resistance, and increased oxygen extraction. Cardiogenic, hypovolemic, and obstructive shock are forms of hypodynamic shock. Conversely, the hyperdynamic state is primarily associated with distributive shock (e.g. sepsis) and is characterized by a normal or increased cardiac index, often in response to reduced systemic vascular resistance, and reduced oxygen extraction as a result of impaired capillary blood flow.

Classically, the pathophysiology of shock is categorized into 4 different types of shock based on the underlying mechanism. Furthermore, a differential diagnosis can be generated for each form of shock (see Table 1).

**CLASSIFICATION**

***Hypovolemic Shock***

This form of shock is the result of reduced circulating blood volume relative to the total capacity of the circulation, resulting in reduced venous return. Prominent features include reduced diastolic filling pressures and volumes, which leads to reduced cardiac preload and cardiac output. Most commonly caused by hemorrhagic conditions, but can also be associated with other etiologies of fluid loss, including massive urinary or gastrointestinal fluid losses. The most common and important conditions to consider include both internal and external hemorrhage, diabetic ketoacidosis, massive diarrhea, and “third-spacing.”

***Cardiogenic Shock***

In cardiogenic shock, there is impairment in cardiac function that results in reduced cardiac output and systemic oxygen delivery that is insufficient to meet energetic demands. Cardiogenic shock is characterized by reduced cardiac output and elevated diastolic filling pressures and volumes. It can result from an acute or a chronic process and can be related to myocardial, valvular, structural, infectious, or toxic factors. The initial compensatory response is to increase systemic vascular resistance and heart rate. Cardiogenic shock is most often encountered in the setting of acute myocardial infarction and is usually associated with significant left ventricular dysfunction, but can also be associated with other complications of acute MI, including acute mitral regurgitation, ventricular septal rupture, free wall rupture with cardiac tamponade, and right ventricular infarction.

***Obstructive Shock***

Obstruction to forward flow at any point in the cardiovascular circuit results in decreased delivery of oxygen and nutrients distal to the point of obstruction. Obstructive processes can increase cardiac afterload (e.g. acute pulmonary hypertension, massive pulmonary embolism) or decrease cardiac preload (e.g. venous obstruction).

***Distributive Shock***

Distributive shock varies from the other three types of shock in that the circulatory defect is in the peripheral circulation, rather than centrally. The result is reduced oxygen extraction and utilization in the setting of normal or increased cardiac output. Sepsis is the most common cause of distributive shock, but other etiologies include anaphylaxis, drug overdose, neurogenic insults, and Addisonian crisis.

**Table 1: Common Etiologies of Shock**

|  |  |  |  |
| --- | --- | --- | --- |
| **Hypovolemic** | **Cardiogenic** | **Distributive** | **Extracardiac/Obstructive** |
| **Hemorrhagic**   * Trauma * Gastrointestinal * Retroperitoneal * Post-operative   **Fluid Depletion**   * Dehydration * Vomiting * Diarrhea * Polyuria   **Interstitial Fluid Redistribution**   * Thermal Injury * Trauma * Anaphylaxis   **Increased Vascular Capacitance**   * Toxins/Drugs * Anaphylaxis * Sepsis | **Myocardial**   * Myocardial ischemia or infarction * Myocardial stunning * Cardiomyopathy * Pharmacologic cardiotoxicity   **Structural/Mechanical**   * VSD * HOCM * Valvular stenosis * Valvular regurgitation   **Infectious**   * Myocarditis * Septic myocardial depression   **Arrhythmia**   * Bradyarrhythmia * Tachyarrhythmia | **Sepsis**   * Bacterial * Viral * Fungal * Rickettsial   **Immunologic**   * Toxic shock syndrome * Anaphylaxis * Neurogenic (spinal shock)   **Endocrinologic**   * Addisonian crisis * Thyroid storm | **Impaired diastolic filling (decreased ventricular preload)**   * Direct venous obstruction * Intrathoracic obstructive tumors   **Increased intrathoracic pressure**   * Tension pneumothorax * Mechanical ventilation * Asthma   **Decreased cardiac compliance**   * Constrictive pericarditis * Cardiac tamponade   **Impaired systole (increased ventricular afterload)**   * Massive PE * Acute pulmonary HTN * LV occlusion or aortic dissection * Air embolus |

**Table 2: Hemodynamic Profiles in Different Types of Shock**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **MAP** | **PCWP** | **CO** | **SVR** | **CVP** | **SvO2** | **Lactate** |
| HYPODYNAMIC STATE |  |  |  |  |  |  |  |
| Hypovolemic shock | ↓ | ↓ | ↓ | ↑ | ↓ | ↓ | ↑ |
| Cardiogenic shock | ↓ | ↑ | ↓ | ↑ | ↑ | ↓ | ↑ |
| Obstructive shock | ↓ | ↔↑ | ↓ | ↑ | ↑ | ↓ | ↑ |
| HYPERDYNAMIC STATE |  |  |  |  |  |  |  |
| Distributive shock | ↓ | ↔↓ | ↔↑ | ↓ | ↔↓ | ↔↑ | ↑ |

Adapted from Vincent et al, Pathophysiology and classification of shock states)

**PATHOPHYSIOLOGY OF SHOCK: HEMODYNAMIC DYSREGULATION**

An understanding of the relationship between cardiac function (i.e. cardiac output) and venous return is important to effectively treat patients in circulatory shock. These concepts will be briefly summarized here, but a detailed discussion of these physiological principles is beyond the scope of this tutorial. The reader is referred to a number of excellent reviews on this topic.[[4]](#endnote-2),[[5]](#endnote-3)

Three key hemodynamic variables are important to consider when thinking about shock: mean arterial pressure, cardiac output, and venous return. Mean arterial pressure (MAP), by definition, is reduced in circulatory shock. MAP is a function of the cardiac output and the systemic vascular resistance (SVR); a reduction in either of these can result in decreased arterial pressure.

, or 

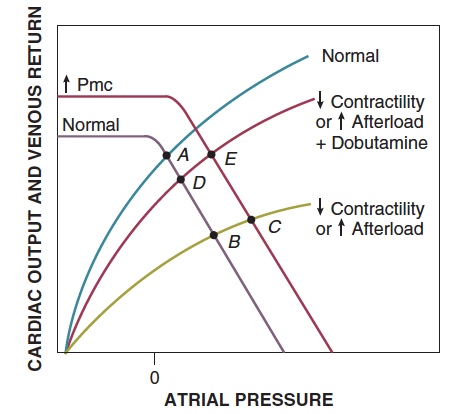
Cardiac output is determined by heart rate and stroke volume (CO = HR x SV), the latter of which is a function of cardiac preload, afterload, and contractility. Because the cardiovascular system (i.e. the heart and vasculature) is a closed system in most contexts, the cardiac output cannot exceed venous return. Therefore, venous return is also an important hemodynamic variable to consider. Venous return is proportional to the difference between the mean systemic pressure (Pms­) and the right atrial pressure (PRA) and inversely proportional to the venous resistance (VR).



Note that the mean systemic pressure is the driving pressure of the circulatory system when the cardiac output is zero (i.e. when the heart is stopped). This is different from the MAP, which is a characteristic of the arterial system only. Because cardiac output must equal venous return, these two functions can be plotted together on a single axis. Cardiac output-venous return curves can aid in understanding the physiological relationship between these two parameters and how specific therapeutic interventions affect each parameter (see Figure 1).

Circulatory flow through each organ system is regulated differently. Systemic perfusion pressure must be sufficient to provide adequate flow to each organ, however, intrinsic and extrinsic factors play a role in modulating perfusion at the local tissue level. This becomes especially important during circulatory failure. Intrinsic factors include autoregulatory mechanisms such as intrinsic vascular tone (i.e. myogenic response), such that a decrease in perfusion pressure is associated with inherent compensatory vasoconstriction, which helps to sustain organ perfusion. Additionally, many local factors are released from metabolically active tissues that cause changes in vascular tone, which allows for matching of local perfusion to metabolic demand. For example, CO2, H+, metabolites of ATP, and nitric oxide are a few of these local regulators.[[6]](#endnote-4) Extrinsic factors also regulate local microvasculature, including the balance of parasympathetic and sympathetic signals, which can be altered in circulatory shock. Finally, each organ system has its optimal autoregulatory range. For example, autoregulation of the cerebral vasculature produces stable cerebral perfusion pressure over a wide range of systemic pressures, generally 40-200 mm Hg. Coronary perfusion pressure can generally be maintained by autoregulatory mechanisms if the systemic pressure is in the range of 40-100 mm Hg. Finally, mesenteric and renal circulations have a narrower range of autoregulation and typically require a mean arterial pressure of >60 mm Hg; below this pressure, autoregulatory mechanisms cannot compensate for the reduced perfusion pressure and the tissues are at risk for ischemia.[[7]](#endnote-5) Autoregulation is why MAP is maintained at a goal of >60-65 mm Hg in hypotensive patients; above this threshold tissue specific vascular autoregulation can maintain perfusion pressure to most organs.

**FIGURE 1**

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**PATHOPHYSIOLOGY OF SHOCK: CELLULAR DYSFUNCTION**

Ischemia, inflammation, and free radical production are all thought to play a role in the pathophysiology of shock at the cellular level.[[8]](#endnote-6) These processes are thought to reflect the common final pathway of cellular damage in all forms of shock. As discussed above, tissue hypoperfusion is a central component, resulting in local tissue hypoxia. Reduced oxygen delivery results in a shift from highly efficient aerobic glycolysis to anaerobic metabolism. Recall that oxidative metabolism produces 38 ATP per molecule of glucose compared to a net production of 2 ATP in anaerobic glycolysis. The cellular supply of energetic substrates becomes rapidly depleted. Pyruvate is metabolized to lactic acid to regenerate NAD+. This results in a reduction of intracellular pH. The combination of reduce ATP stores and a reduction in pH will eventually lead to irreversible cellular damage, contributing to the progression of shock and multiple organ dysfunction.

Inflammation plays a key role in septic shock and hypovolemic shock secondary to trauma. Septic shock, in particular is associated with an inflammatory response to an underlying pathogen and elaboration of circulating inflammatory mediators, such as tumor necrosis factor-α, interleukin 1-β, and interleukin 6. These and other circulating factors mediate the systemic inflammatory response, including activation of inducible nitric-oxide synthase (iNOS), which may contribute to systemic vasodilation. Furthermore, activation of the coagulation cascade and formation of microthrombi can cause localized ischemia and worsen organ dysfunction.

Cellular and tissue damage secondary to the generation of free radicals is also thought to contribute to the pathogenesis of shock, especially following reperfusion of ischemic tissues (e.g. cardiogenic shock following reperfusion for acute MI). Ischemia results in depletion of high-energy substrates such as ATP, leading to a reciprocal increase in their downstream metabolites. The metabolites of ATP include adenosine, inosine, and hypoxanthine, the latter of which is converted to xanthine and uric acid by xanthine oxidase in a reaction that requires O2. Superoxide (O2-) is also produced in this reaction. With resuscitation or reperfusion, the addition of O2 drives the reaction forward, producing significant quantities of free radicals that lead to further tissue damage and cellular dysfunction, as well as subsequent inflammation.[[9]](#endnote-7)

**PATHOPHYSIOLOGY OF SHOCK: ORGAN SYSTEM DYSFUNCTION**

Every organ is susceptible to ischemia, however, because of autoregulatory mechanisms and differences in metabolic activity of each tissue, the threshold for ischemic insult to each organ varies. Generally, the renal and mesenteric circulations require the highest systemic pressures to maintain organ perfusion (>60 mm Hg) and, thus, these organs are the most susceptible to ischemic damage from circulatory shock. In contrast, the cerebral and coronary circulations exhibit effective autoregulation across a broader range of systemic pressures. Table 3 lists many of the organ-specific complications that can be associated with circulatory shock. It is important to remember that the susceptibility to any complication varies from one patient to another depending on underlying comorbidities. For example, a patient with extensive atherosclerotic disease will be more susceptible to mesenteric ischemia or myocardial ischemia than a patient with minimal underlying atherosclerosis. A patient with a history of CAD or structural heart disease might be more susceptible to myocardial ischemia, myocardial depression, or arrhythmias.

**TABLE 3: ORGAN SYSTEM DYSFUNCTION IN CIRCULATORY SHOCK**

|  |  |
| --- | --- |
| **Organ System** | **Potential Complications in Shock** |
| Central Nervous system | Ischemic encephalopathy  Cortical necrosis |
| Respiratory system | Acute respiratory failure  Acute lung injury  Acute respiratory distress syndrome |
| Heart | Myocardial ischemia  Myocardial depression  Tachycardia  Arrhythmias (including supraventricular tachycardia and ventricular ectopy secondary to ischemia) |
| Kidneys | Acute tubular necrosis  Prerenal failure |
| Gastrointestinal system | Mesenteric ischemia  Acalculous cholecystitis  Ileus  Pancreatitis  Erosive gastritis  Gut translocation of bacteria (disruption of barrier function) |
| Liver | Ischemic “shock” liver  Intrahepatic cholestasis |
| Hematologic system | Consumptive coagulopathy, DIC |
| Metabolism | Hyper-/hypoglycemia  Hypertriglyceridemia |

Adapted from Kumar et al., *Critical Care Medicine*, 2014

**Approach to the patient in shock**

**DIAGNOSTIC APPROACH**

The diagnosis of a patient with shock or compensated shock (pre-shock) is primarily based on clinical signs and symptoms. Studies have shown that the delays in diagnosis significantly impact on mortality. Clinical evaluation will often suggest the diagnosis of shock and a careful assessment may even give insight into the etiology, however, the clinical signs and symptoms often underestimate the true state of the patient.[[10]](#endnote-8) Appropriate therapy should not be delayed for confirmatory laboratory or imaging studies.

The clinical evaluation of patients with suspected shock requires a problem-oriented approach to the history and physical examination and this evaluation should be carried out as therapy is being initiated. Specific information regarding volume depletion (bleeding, vomiting, diarrhea, excessive urination, orthostatic dizziness), cardiac dysfunction (angina, exertional dyspnea, orthopnea, edema), recent changes in medication, or evidence of recent infection (pneumonia, UTI, non-healing ulcers) should be sought.

Physical exam should focus on signs of systemic hypoperfusion, with special attention to the cardiac, neurologic, and cutaneous systems. Common cardinal signs include tachycardia, tachypnea, oliguria, and hypotension. Blood pressure may be variable depending on the stage; it may be normal or elevated in early or compensated shock due to increased sympathetic activity. Progression of shock will result in hypotension with mean arterial pressures falling below 60-65 mm Hg. It is important to ascertain the patient’s normal blood pressure in this setting. A “normal” blood pressure might not provide adequate tissue perfusion in a patient who is usually hypertensive (i.e. relative hypotension). Other findings include cool extremities with skin mottling, pallor, or cyanosis in hypodynamic shock, or warm extremities in hyperdynamic states. Patients with hypovolemic shock will have a flattened JVP, whereas those with cardiogenic shock will usually have an elevated JVP. Other signs of a cardiogenic etiology include an S3, S4, regurgitant murmurs, or hepatjugular reflux. Patients with obstructive causes of shock will exhibit signs consistent with the obstructive process. For example, patients with a massive pulmonary embolism may have significant dyspnea, pleuritic pain, and signs of RV failure (RV heave, right-sided S3, edema). Whereas patients with pericardial tamponade may exhibit Kussmaul’s sign, pulsus paradoxus, and distant heart sounds.

Initial laboratory studies should be obtained, including a complete blood count, coagulation studies, electrolytes, renal studies, serum lactate, and arterial blood gas measurements. The acid-base status of the patient should be assessed and may give insight into the severity of tissue hypoperfusion, as well as the etiology. Serum lactate is important, as it is a direct product of anaerobic metabolism and elevated levels suggest tissue hypoperfusion. Moreover, significantly elevated lactate (>4.0 mmol/L) is an independent predictor of mortality in patients with sepsis, and some data suggests that elevated serum lactate is also predictive of mortality in patients with cardiogenic shock.[[11]](#endnote-9),[[12]](#endnote-10),[[13]](#endnote-11) Additional laboratory studies might be necessary based on findings from the clinical examination.

Imaging studies are often helpful to support or confirm diagnostic hypotheses. A chest radiograph should be obtained and may reveal evidence of pneumonia in a patient with sepsis, pulmonary edema in a patient with suspected cardiogenic shock, and may reveal evidence of tension pneumothorax, a widened mediastinum, or an enlarged cardiac silhouette. A CT scan should be obtained in the case of suspected pulmonary embolism or aortic dissection. There has been an increased utilization of echocardiography in the evaluation of patients with shock. Echocardiography can be rapidly performed at the bedside to assess for anatomic or functional cardiac abnormalities that might be causing the circulatory failure.

**Table 3: Common Findings in Circulatory Shock**

|  |  |  |
| --- | --- | --- |
| **Clinical** | **Laboratory** | **Hemodynamic** |
| Tachycardia  Tachypnea  Neck vein distention or flattening  HJR, S3, S4, regurgitant murmurs  Cool distal extremities  Skin mottling, pallor, cyanosis  Abdominal pain  Oliguria (<0.5 mL/kg/hr)  Altered sensorium | Increased neutrophil count  Metabolic acidosis (can be non-gap or elevated gap, depending on etiology)  Hyperlactatemia  Reduced or elevated SvcO2 | Hypotension  SBP <90 mmHg or  MAP <70 mmHg  Elevated or reduced CVP  Elevated PAOP |

**MANAGEMENT OF THE PATIENT WITH CIRCULATORY SHOCK**

Recall that shock is defined as a “common final pathway” of circulatory failure with characteristic signs and symptoms and that multiple etiologies can lead to shock. This definition suggests both a general approach to the treatment of shock, focused on maintaining adequate tissue perfusion, and a specific treatment approach directed at the specific etiology (e.g. percutaneous coronary intervention in patients with cardiogenic shock secondary to acute myocardial infarction, or initiation of antibiotics in patients with septic shock). Both general and etiology-specific therapies are important and should be administered expeditiously. This section will focus on the general approach to shock. The subsequent section will discuss specific treatment approaches for the common etiologies of cardiogenic shock.

The importance of rapid treatment initiation cannot be understated, as delays in instituting treatment impact negatively upon outcomes. Therefore, clinicians should initiate resuscitative efforts in patients with shock even while the underlying etiology is still being determined. As always in critical patients, attention must be given to ensuring adequate oxygenation, ventilation, and circulation. The “VIP” approach to the management of shock proposed by Weil and Shubin is a useful mnemonic for recalling the components essential to resuscitation in these patients.[[14]](#endnote-12)

* **Ventilate** – ensure adequate ventilation by administering supplemental oxygen via mechanical ventilation, if necessary. In the majority of patients presenting with shock, there should be a low threshold to intubate, as patients with severe dyspnea, hypoxemia, or worsening acidemia can rapidly decompensate, leading to respiratory and/or cardiac arrest. Furthermore, mechanical intubation can reduce the oxygen demand contributed by respiratory muscles (which may be responsible for up to 40% of systemic oxygen consumption) and reduces LV afterload by increasing intrathoracic pressure.
* **Infuse** – fluid resuscitation. The goals of fluid resuscitation are to improve microvascular circulation and augment cardiac output. It is important to monitor fluid status closely to avoid unwanted edema. The aim of fluid resuscitation is to increase preload independence (i.e. shift toward the plateau portion of the Frank-Starling curve).
* **Pump** – Ensure optimal pump function. If hypotension is severe or if the patient is unresponsive to fluid resuscitation, then pharmacologic pressor support or inotropic therapy should be initiated. Pump support is usually augmented pharmacologically, but can also be supported mechanically. Refer to the other modules in this tutorial for detailed information relating to vasopressors, inotropes, and circulatory-assist devices.

The patient should have one or two large-bore (≥16 guage) peripheral intravenous catheters inserted and if there is evidence of tissue hypoperfusion, if SBP <90 mmHg, or if the MAP is <60-65 mmHg, then a fluid challenge should be initiated. An arterial pressure catheter should be inserted for hemodynamic monitoring and frequent blood sampling. Consider insertion of a central venous catheter for rapid administration of fluids and vasopressor agents, if necessary. (See module on *Hemodynamic Monitoring* for more information). Recall that pulse oximetry may be unreliable because of peripheral vasoconstriction. The patient should also be maintained on continuous ECG monitoring.

Serial monitoring of arterial blood gas values, as well as central venous (ScvO2) or mixed venous oxygen saturation (SvO2) and serum lactate. These parameters give considerable insight into the degree of ongoing tissue hypoperfusion or the adequacy of resuscitation efforts.

Another sensitive indicator of systemic tissue perfusion is urine output. The kidneys receive 20% of the total systemic oxygen delivery and are, therefore, extremely sensitive to changes in renal blood flow. Changes in urine output are monitored with a Foley catheter and can provide valuable information about vital organ blood flow. Note, however, that in patients that have received diuretics or who have a history of renal failure, urine output may be a less useful indicator of successful resuscitation.

**ADMINISTERING A FLUID CHALLENGE**

When performed in a hemodynamically unstable patient, a fluid challenge can give the clinician insight into how a patient is likely to respond to intravenous fluids. Conventional (static) signs that a patient may require fluids include tachycardia, diminished skin turgor, thirst, dry axillae, elevated hematocrit, hypotension, decreased skin temperature, increased BUN/Cr, and increased urine osmolarity. These signs lack sensitivity and specificity for predicting a patient’s response to a fluid challenge.[[15]](#endnote-13) Even filling pressures (i.e. CVP, PAOP) represent a static measurement with poor predictive value. Dynamic tests such as orthostatic measurements, passive leg raising, assessment of pulse pressure variation in ventilated and sedated patients, and administration of a fluid challenge have been shown to have more value in predicting response to fluid administration.

The ultimate goal of a fluid challenge is to determine whether the patient is “preload-dependent”, that is, whether the patient’s cardiac output has not yet reached the plateau portion of the Frank-Starling curve.

Vincent and De Backer suggest that four parameters should be defined prior to administering a fluid challenge:[[16]](#endnote-14)

* Selection of fluids – crystalloids are generally preferred, however in selected patients with hypoalbuminemia, colloids may be appropriate
* Rate of fluid infusion – fast enough to induce a quick response, but not so fast as to induce a stress response; generally 300-500 cc over 20-30 minutes
* Define the objective of the fluid challenge – for example, increase in MAP, increase in urine output, or decrease in heart rate. These should be quantitatively defined goals.
* Define the safety limits of the fluid challenge – pulmonary edema is the most common; fluid challenge should be stopped in the case of non-response to avoid complications

**THERAPEUTIC GOALS IN RESUSCITATION**

Because tissue perfusion is dependent on both cardiac output and driving pressure, therapeutic goals in the general treatment of shock should focus on optimizing both of these parameters to ensure adequate tissue perfusion. In general, the MAP should be maintained above 60-65 mm Hg and the cardiac index >2.1 L/min/m2. Other parameters that influence oxygen delivery should be optimized, including hemoglobin (>9 g/dL), arterial oxygen saturation (>92%), ScvO2 >70% or (SvO2 >60%). Although these parameters are all important in ascertaining the clinical state of the patient, it is also important to follow organ specific signs such as normalization of skin findings, increased urine output, and improvement in sensorium.

**Management of Specific Forms of Shock**

**CARDIOGENIC SHOCK**

Cardiogenic shock is defined by a reduced cardiac output and evidence of systemic hypoperfusion despite adequate intravascular volume and is associated with sustained hypotension (systolic BP <90 mm Hg), a reduced cardiac index (<2.2 L/min/m2), elevated filling pressures (PAOP >15 mm Hg), and the absence of other conditions that can secondarily cause myocardial dysfunction, such as hypoxia or acidosis.[[17]](#endnote-15) Cardiogenic shock occurs most commonly as a complication of acute myocardial infarction (AMI). The incidence of cardiogenic shock in AMI has been estimated at 7-8% for decades, however, with development and widespread utilization of percutaneous coronary intervention (PCI), the incidence appears to have decreased slightly to approximately 6% of cases.

Cardiogenic shock is a medical emergency that requires rapid evaluation to determine the patient’s hemodynamic status and the etiology of the shock state. Concomitant initiation of therapeutic interventions is also necessary. A targeted history and physical examination should be conducted. The history may reveal underlying risk factors for coronary artery disease, or a prior history of an acute coronary syndrome that might suggest poor cardiac reserve. Patients are usually tachycardic, tachypneic, and may have cool extremities with mottling. In early stages of shock, the blood pressure may be normal or only slightly reduced in the setting of maximal sympathetic output. Oliguria and altered mental status are other signs of systemic hypoperfusion. Jugular venous distention and pulmonary rales are often present and indicate increased filling pressures. Third and fourth heart sounds are often present. Murmurs of mitral regurgitation or a ventricular septal defect, if present, may give insight into the cause of cardiogenic shock. Muffled heart sounds and pulsus paradoxus suggest cardiac tamponade. An ECG and echocardiography should be performed. A chest radiograph should be obtained, as well as basic labs, including CBC, electrolytes (including Mg2+, Ca2+), coagulation studies, and cardiac enzymes.

As discussed above, the initial management strategy should focus on providing adequate ventilation and oxygenation; intubation and mechanical ventilation may be required. Central venous and arterial access should be obtained. Electrolyte abnormalities, acid-base disorders, and arrhythmias should be appropriately managed. Pain management is also important. A fluid challenge should be attempted in the absence of frank pulmonary edema. Many patients in cardiogenic shock have a reduced stroke volume with compensatory tachycardia and may respond to fluid resuscitation.

A patient with cardiogenic shock that fails to respond to fluids should be considered for invasive hemodynamic monitoring and vasopressor therapy. Invasive hemodynamic monitoring with a pulmonary artery catheter allows the clinician to more precisely ascertain the hemodynamic status of the patient, to more accurately estimate cardiac filling pressures, and to titrate vasopressors and inotropes. In general, vasopressors are utilized in patients who fail to respond to fluid resuscitation to maintain MAP above 60-65 mm Hg and to facilitate tissue perfusion, as evidenced by biochemical parameters such as lactate and ScvO2. Inotropic agents are used to augment cardiac output in the setting of acute cardiogenic shock. Dobutamine is generally the first line agent in this setting. These agents should be titrated to the lowest dose possible to maintain adequate tissue perfusion and coronary perfusion pressure while minimizing the increased myocardial oxygen demand associated with these agents. (For more detailed information, refer to the module on Vasopressors and Inotropes.) Mechanical circulatory support is often utilized concomitantly with pharmacologic agents. Initiation of intra-aortic balloon pump (IABP) counterpulsation can augment cardiac output and coronary perfusion by reducing afterload and increasing diastolic perfusion pressure, respectively. Importantly, these effects are obtained without increasing myocardial oxygen consumption. Early observational studies and small clinical trials suggested that a mortality benefit might be associated with the use of IABP counterpulsation in patients with cardiogenic shock complicating acute MI.[[18]](#endnote-16) However, recent studies have failed to show an effect on mortality. In fact, the recently published IABP-SHOCK II trial is the largest trial conducted thus far to assess the efficacy of IABPs in this setting. No mortality benefit was observed at either 28 days or 12 months with the use of IABP counterpulsation.[[19]](#endnote-17),[[20]](#endnote-18) (See module on Mechanical Circulatory Support for more information on IABPs).

In the majority of cases, cardiogenic shock develops as a result of myocardial ischemia or infarction. In these patients, reperfusion is a crucial component of therapy. Only 20% of patients who develop cardiogenic shock associated with acute MI present with shock; most patients who go on to develop circulatory shock do so >6 hours after presentation.[[21]](#endnote-19) Therefore, the importance of early revascularization cannot be understated. Although a mortality benefit has been demonstrated with thrombolytic therapy in acute MI, this benefit is abolished in patients who undergo thrombolysis while in cardiogenic shock. However, thrombolysis prior to the onset of cardiogenic shock likely reduces the risk of progression to shock.[[22]](#endnote-20) However, in the last 20 years, percutaneous coronary intervention (PCI) has largely replaced thrombolytic therapy as the first-line treatment for acute MI. The benefit of early revascularization in patients with acute MI complicated by cardiogenic shock was demonstrated in the SHOCK trial. Although this trial was underpowered to detect a mortality benefit at 30 days, there was a trend toward reduced mortality at this time point with early revascularization (46.7% vs. 57.0%, p=0.11). Furthermore, significant reductions in mortality were demonstrated at both 6 months and 12 months with early revascularization.[[23]](#endnote-21),[[24]](#endnote-22)  The 2013 ACC/AHA guidelines recommend that patients with cardiogenic shock secondary to acute myocardial infarction undergo either PCI or CABG (regardless of time since onset), or if patients are not candidates for PCI or CABG, they should receive thrombolytic therapy (Class I recommendations).[[25]](#endnote-23)

**SEPTIC SHOCK**

Severe sepsis and septic shock are extremely common clinical entities. Estimates of the annual incidence vary significantly, from nearly 900,000 to >3.1 million cases in the US, depending on the reporting method used.[[26]](#endnote-24) The incidence of severe sepsis is increasing, largely due to aging of the population, improved medical care that results in more patients with chronic illnesses that predispose to infection, and the increase prevalence of virulent drug resistant organisms. The mortality rate of septic shock remains high, although recent evidence suggests that the mortality rate has declined over the last decade,[[27]](#endnote-25) perhaps due to the development and widespread implementation of evidence-based treatment protocols.

Identification of patients with septic shock involves a similar approach to those with cardiogenic shock, including a targeted history and physical examination, fluid resuscitation, optimization of…

Patients with septic shock can exhibit a complex hemodynamic profile, although classically, it is hyperdynamic, with increased cardiac output in the face of reduced systemic vascular resistance

Treatment protocols for patients with severe sepsis or septic shock have evolved over the last two decades. The Surviving Sepsis Campaign (SSC) guidelines were initially published in 2004 and have since been revised.[[28]](#endnote-26),[[29]](#endnote-27) The basic principle behind the SSC involves *early goal-directed therapy*. In other words, patients benefit most when severe sepsis and septic shock is recognized early in its course and when appropriate antibiotics and resuscitation can be rapidly initiated. Furthermore, it is clear that resuscitation efforts should be guided both by specific blood pressure targets and specific parameters indicative of adequate tissue perfusion. This was first demonstrated in a pivotal trial published by Rivers and colleagues in 2001.[[30]](#endnote-28)

Antibiotic therapy selection should be broad, covering any organisms that are likely to be associated with the sepsis syndrome. Initiation of antibiotic treatment within 1 hour of the diagnosis is the goal. Broad-spectrum antibiotics should be maintained until speciation and susceptibility data are obtained, and only then should they be narrowed. Infectious disease consultation should also be considered. Identification of the most likely source will help in antibiotic selection and will aid in identifying the underlying source. Imaging studies may be needed to identify the infectious source. Finally, if surgical drainage is required, it should be done as early as possible in the patient’s course, preferably within the first 12 hours.

Hemodynamic and microvascular dysfunction predispose the patient to global hypoperfusion, which can lead to multiple organ dysfunction and, eventually, death. Early resuscitative efforts restore adequate tissue perfusion, preserving organ function and improving outcomes. Fluid resuscitation and vasopressors are used to restore and maintain cardiovascular stability. According to the current SSC guidelines, treatment endpoints include the following:

* Mean arterial pressure (MAP): ≥65 mm Hg
* Central venous pressure (CVP): 8-12 mm Hg
* Urine output (UOP): ≥0.5 ml/kg/hr
* Central venous oxygen saturation (ScvO2): ≥70%
* Mixed venous oxygen saturation (SvO2): ≥65%

Serum lactate levels should also be followed and can be used in conjunction with these parameters to optimize resuscitative efforts. As mentioned above, serum lactate levels also carry prognostic significance. It is important to remember that the SSC guidelines are not a substitution for clinical judgment and by no means apply to every clinical situation. For example, although a MAP of >65 mm Hg is a therapeutic target in the guidelines, this target may be inadequate to ensure tissue perfusion in a patient with baseline untreated hypertension.

The goal of fluid resuscitation is to optimize cardiac filling pressures, thus augmenting cardiac output. A fluid challenge can be administered as described above. Rapid administration of 2-3 L of crystalloid (either normal saline or lactated Ringer’s) is reasonable. It is important to monitor the patient’s oxygenation status in the setting of rapid fluid administration; patients may require intubation and mechanical ventilation. Patients with MAP <65 mm Hg despite adequate fluid resuscitation will require treatment with vasopressors to maintain adequate arterial pressure and tissue perfusion. Briefly, norepinephrine is the preferred first-line vasopressor for the treatment of septic shock. Dopamine, which was once commonly used, has fallen out of favor as a first-line agent, owing to increased mortality and an increased risk of arrhythmias.[[31]](#endnote-29) If a second agent is needed, infusion of either epinephrine or vasopressin (0.03 U/min) is recommended.

Finally, the use of corticosteroids in the treatment of septic shock has been debated for years. The rationale for exogenous corticosteroid treatment is that patients with septic shock may have a “relative adrenal insufficiency.” Although the results of early studies were mixed, one study published in 2000 suggested that patients with high cortisol levels and poor response to ACTH stimulation had higher 28-day mortality rates and a subsequent study by the same group demonstrated that low-dose corticosteroids improved the time to resolution of shock as well as mortality.[[32]](#endnote-30),[[33]](#endnote-31) A subsequent large, multicenter randomized controlled trial (CORTICUS) examined the use of corticosteroids in patients with septic shock and found no mortality benefit, although it did confirm that corticosteroids shorten the time to reversal of shock.[[34]](#endnote-32) Based on these studies, the current SSC guidelines recommends that corticosteroids not be routinely used in patients with septic shock, but be reserved for those patients who remain hypotensive despite fluid resuscitation and vasopressor therapy. The recommended treatment in this setting is hydrocortisone, 200 mg daily until pressor support is no longer required.

**Conclusion**

Circulatory shock is a common clinical syndrome with a high morality rate. The broad differential diagnosis and the variable presentations of circulatory shock contribute to the complicated process of managing these critically ill patients. As in most areas of medicine, a systematic and efficient approach to evaluating and managing circulatory shock is extremely important. Prompt evaluation, rapid initiation of therapeutic measures according to established guidelines, and close monitoring are all crucial components to improving outcomes for these patients.

Cardiogenic and septic shock are the most common forms of shock encountered in the cardiac ICU setting. Evolution and implementation of new treatments and protocols (e.g. PCI for cardiogenic shock in AMI, SSC in septic shock) have led to improved outcomes in recent years.

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