Introduction

Introduction/Purpose Statement
Failure of the normal regulatory mechanisms in the body can lead to rapid and profound shock. The purpose of this home study is to review the pathophysiology of cardiogenic, hypovolemic, anaphylactic, and neurogenic shock. A brief review of sepsis and septic shock is also covered.

Target Audience
This home study was designed for the novice critical care or telemetry nurse; however, other health care professionals are invited to complete this packet.

Content Objectives
1. List the classifications of shock.
2. List the functions of the cell and the microcirculation.
3. Describe the stages of shock.
4. Describe three major mechanisms put into action to compensate for shock.
5. Define terms related to shock.

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An Overview of Shock

Definition
Shock is a state of inadequate perfusion relative to tissue demands.

Classification
The integrity of the circulatory system is dependent on: (a) efficient cardiac pump, (b) an adequate blood volume, and (c) a healthy vascular bed. The loss of any one of these three essential components leads to one of the three major classes of shock:
- **Cardiogenic**: loss of an efficient cardiac pump
- **Hypovolemic**: inadequate blood volume
- **Distributive** (neurogenic, anaphylactic, and septic): an unhealthy vascular bed

The cascading events of shock begin with inadequate oxygen transport and cellular dysfunction, which proceed to tissue and vascular disturbances, and end with organ dysfunction or failure.

Oxygen Transport
Oxygen transport has two components: oxygen delivery \((\text{DO}_2)\) and oxygen utilization /consumption \((\text{VO}_2)\). Oxygen delivery \((\text{DO}_2)\) is the product of cardiac output and arterial oxygen content. Calculation of the arterial oxygen content depends on (1) the hemoglobin content of blood, (2) the oxygen saturation of hemoglobin, and (3) the amount of oxygen bound to hemoglobin. Changes in any of these three factors and/or changes in cardiac output alters oxygen delivery to tissues.

Normally, systemic oxygen delivery is five times greater than oxygen consumption. In other words, 20 percent of \(\text{DO}_2\) is absorbed \((\text{VO}_2)\), while 80 percent of \(\text{DO}_2\) remains in returning venous blood. The body adjusts to maintain this ratio; usually by increasing or decreasing cardiac output.

Tissue oxygen utilization cannot be directly measured; however, the calculation of \(\text{VO}_2\) infers utilization and serves as a guide to the adequacy of tissue perfusion and cellular metabolism. Factors that determine \(\text{VO}_2\) are: (1) \(\text{DO}_2\), (2) state of microcirculation, and (3) cellular milieu.

Life at the Cellular Level
The cell is the unit, or building block, of all living things. The cell has several structures that are vital for functioning:

1. **Cell membrane**: a barrier with selective permeability between plasma and interstitial fluid that allows interchanges to occur between the cell and its environment. When damaged, it becomes permeable to almost anything.
2. **Nucleus**: controls the biochemical reactions; site of cellular reproduction.
3. **Cytoplasm**: the protoplasm within the cell but outside of the nucleus; site of most cellular activity.
4. **Organelles**: specialized metabolic machinery of the cell that produce and store protein, detoxify contents, aid in phagocytosis, and provide cellular energy.

Cellular metabolism refers to all chemical and energy transformations that occur in the body, including anabolic and catabolic reactions. Carbohydrates, proteins, and fats are oxidized, producing \(\text{CO}_2\), \(\text{H}_2\text{O}\), heat, and chemical energy. This oxidation (catabolism) is a complex, slow process which liberates energy (ATP) in small, usable amounts.

The Microcirculation
The term microcirculation is used to describe a group of blood vessels within the tissues that acts as an independent organ unit in regulating blood supply to the tissues. The functions of the microcirculation are to:
- Deliver nutrients to, and remove wastes from, cells
- Adjust blood flow in response to tissue metabolic needs
- Maintain intravascular/interstitial osmotic equilibrium

The portion of the vascular bed lying between the arterioles and the venules is considered the microcirculation. There are no distinct boundaries between the divisions, and the arrangement and distribution differ from tissue to tissue depending on architecture and function.

The artery has a strong, smooth muscle wall, and directs blood to capillary beds and controls pressure of the blood delivered to those beds. Arterioles are
referred to as “resistance vessels.” Adjustments to
the blood flow, and therefore, tissue perfusion
pressure, is made by the sympathetic innervation and
vasomotor influences.

The arteries branch into the metarterioles, and from
there into the pre-capillary sphincters. The
capillaries at the end of the arterial system form a
junction with the venous system.

It is in the capillary system that nutrients, oxygen and
waste products are exchanged from the arterial side
to the venous side. Once that process is complete,
the blood exists into the venules and finally the veins.

The microcirculation is controlled
by the metabolites
from surrounding tissues. These metabolites have an
intrinsic capacity to regulate blood flow to
compensate for changes in the perfusion pressure and
metabolic needs. There is a delicate balance between
blood flow and tissue demand that is maintained by
the (1) autonomic nervous system (modulates
vascular tone), (2) humoral, (3) chemical, and (4)
metabolic influences.

Moment to moment redistribution of blood flow
through the microcirculation is known as
autoregulation. Actively metabolizing cells release
local mediators such as K⁺, H⁺ ion, CO₂, and lactic
acid, causing local vasodilatation in order to deliver
greater blood flow to vascular beds with higher
metabolic activity.

Pathophysiology of Shock: Initial Stage

This is the stage in which there are (theoretically)
cellular changes in response to shock. There are also
no clinical signs or symptoms except elevated lactate
levels.

In the initial stage of shock, the cell switches from
aerobic metabolism to anaerobic metabolism, which
causes decreased energy production and increased
lactic acid levels. Diminished blood flow to the
microcirculation reduces oxygen delivery and
sequesters metabolic by-products, thereby reducing
oxygen delivery and utilization. The cell metabolism
suffers, and the cell begins to deteriorate.

Compensatory Stage of Shock

The homeostatic compensatory mechanisms of the
body are activated by decreased cardiac output.
Compensation is mediated through neural, hormonal,
and chemical changes.

Neural Compensation

Baroceptors located in the aorta and carotid bodies
sense a decrease in the blood pressure. Messages are
sent to the medullary vasomotor center that
stimulates the sympathetic nervous system. The SNS
uses the endogenous catecholamines (epinephrine
and norepinephrine), which are released from the
adrenal medulla, to:

1. Constrict the blood vessels in the skin, GI tract
   and kidneys
2. Dilate the blood vessels in the skeletal muscles
   and coronary arteries
3. Sweat
4. Increase the heart rate and contractility
5. Increase the rate and depth of breathing
6. Dilate the pupils

Hormonal Compensation

Mediated through the sympathetic nervous system,
humoral compensation begins. The anterior
pituitary releases ACTH, which causes a release of
mineralocorticoids and glucocorticoids. The
mineralocorticoids balance the sodium and water
levels. The glucocorticoids regulate the metabolic
function of the body through the stress response.
Cortisol sensitizes the muscle of the arteriole to the
effects of catecholamines.

The posterior pituitary releases ADH, causing
vasoconstriction and renal retention of water.

The kidneys, which are flow dependent, also sense
the decreased blood pressure. The kidneys release
renin in response, which then stimulates the
angiotensin and aldosterone systems. These
hormones cause:

- Retention of sodium and water
- Increased blood volume in the major blood
   vessels because of water retention and
   vasoconstriction of the smaller blood vessels
- Decreased urine volume and sodium
   excretion
• Increased potassium excretion and increased urine osmolarity

**Chemical Compensation**

Hypoxemia and cellular hypoxia cause an increase in respiratory depth and rate. The acid-base balance is disturbed with the “blowing off” of CO2, which leads to respiratory alkalosis. The combination of hypoxemia and alkalosis adversely affects the level of consciousness.

**Progressive Stage of Shock**

In this stage of shock, previously helpful compensatory responses are no longer effective. Severe hypoperfusion to all organ systems causes multi-organ dysfunction syndrome (multi-system organ failure). The microcirculation loses the ability to autoregulate blood flow, leading to decreased blood volume returning to the central blood vessels. This causes further organ hypoperfusion.

**Refractory Stage of Shock**

This final and irreversible stage reflects the very last part of a patient’s life. The cellular and organ destruction has been so severe that death is inevitable.

**Essential versus Non-essential Organs**

The body long ago developed a priority list for scant amounts of blood. On the top of the list:

- Brain
- Heart
- Lungs

These organs will receive the most blood possible during shock through stimulation of the beta receptors, which causes vasodilation.

The other organs of the body, such as the skin and gut, have primarily alpha-receptors, which when stimulated cause vasoconstriction. They are considered to be “non-essential organs.”

**Organ-Specific Effects of Shock**

**Brain - Essential Organ**

Beta adrenergic stimulation dilates cerebral vessels to attempt to maintain enough flow for a MAP of 50.

**Heart - Essential Organ**

In all forms of shock except cardiogenic shock, the myocardium experiences a protective flow. Autoregulation maintains coronary flow as long as arterial pressure does not fall below 70 mm/Hg. The deterioration of heart function makes shock irreversible.

**All other organs are considered biologically expendable.**

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