Division 1
Introduction to Advanced Prehospital Care

Topics
- Fluids & fluid imbalances
- IV Therapy
- Hypoperfusion
- Shock

Fluids and Fluid Imbalances
Water is the most abundant substance in the human body.

Fluids
- Body weight of adult male 55-60%, female 50-55%, newborn 75-80%
  - Very little in adipose tissues
  - Loss of 20% - fatal
  - Elderly - decreases to 45-50% of body weight
    - R/T decreased muscle mass, smaller fat stores, and decrease in body fluids

Where the Water Is Found
- Intracellular fluid—fluid inside the cells
- Extracellular fluid—all the fluid outside the body cells
  - Intravascular fluid—fluid within the circulatory system
  - Interstitial fluid—fluid outside of the cell membranes but not within the circulatory system
Fluid Shifts in Infants

- predisposed to serious, rapid fluid volume deficit
  - limited ability to concentrate urine
  - proportionately greater ratio of surface area to volume
  - higher metabolic rate

Compartments

Intracellular (ICF)
- Fluid within the cells themselves
- 2/3 of body fluid
- Located primarily in skeletal muscle mass
- Provide nutrients for metabolism:
  - High in K, Po4, protein
  - Moderate levels of Mg, So4
- Assists in cellular metabolism

Extracellular (ECF)
- 1/3 of body fluid
- Comprised of 3 major components
  - Intravascular
    - Plasma
  - Interstitial
    - Fluid in and around tissues
  - Transcellular
    - Over or across the cells
Compartments

**Extracellular**
- Nutrients for cell functioning
  - Na
  - Ca
  - Cl
  - Glucose
  - Fatty acids
  - Amino Acids

**Intravascular Component**
- Plasma
  - Fluid portion of blood
  - Made of:
    - Water
    - Plasma proteins
    - Small amount of other substances

**Blood Components**

(graphic showing blood components: White blood cells, Red blood cells, Platelets, Plasma, proteins, etc.)
Compartments

- **Interstitial component**
  - Made up of fluid between cells
  - Surrounds cells
  - Transport medium for nutrients, gases, waste products and other substances between blood and body cells
  - Back-up fluid reservoir

Compartments

- **Transcellular component**
  - 1% of ECF
  - Located in joints, connective tissue, bones, body cavities, CSF, and other tissues
  - Potential to increase significantly in abnormal conditions

Regulation of Fluids in Compartments

- **Osmosis**
  - Movement of water through a selectively permeable membrane from an area of low solute concentration to a higher concentration until equilibrium occurs
  - Movement occurs until near equal concentration found
  - Passive process
Regulation of Fluids

Diffusion
- Movement of solutes from an area of higher concentration to an area of lower concentration in a solution and/or across a permeable membrane (permeable for that solute)
- Movement occurs until near equal state
- Passive process

Osmosis versus Diffusion

Osmosis
- Low to high
- Water potential

Diffusion
- High to low
- Movement of particles

Both can occur at the same time

Regulation of Fluids

Active Transport
- Allows molecules to move against concentration and osmotic pressure to areas of higher concentration
- Active process – energy is expended
Active Transport

- Na / K pump
  - Exchange of Na ions for K ions
  - More Na ions move out of cell
  - More water pulled into cell
  - ECF / ICF balance is maintained

Active Transport

- Insulin and glucose regulation
  - CHO consumed
  - Blood glucose peaks
  - Pancreas secretes insulin
  - Blood glucose returns to normal

Glucose Breakdown (1 of 2)

- Stage one, glycolysis, is anaerobic (does not require oxygen). It yields pyruvic acid, with toxic by-products such as lactic acid, and very little energy.
Stage two is aerobic (requires oxygen). In a process called the Krebs or citric acid cycle, pyruvic acid is degraded into carbon dioxide and water, which produce a much higher yield of energy.

Osmolality

- Concentration of body fluids – affects movement of fluid by osmosis
- Reflects hydration status
- Measured by serum and urine
- Solutes measured - mainly urea, glucose, and sodium
- Measured as solute concentration/Kg

Factors that affect Osmolality

- Serum
  - Increasing Osm
    - Free water loss
    - Diabetes Insipidus
    - Na overload
    - Hyperglycemia
    - Uremia
Factors that affect Osmolality

- Serum
  - Decreasing Osm
    - SIADH
    - Renal failure
    - Diuretic use
    - Adrenal insufficiency

Factors that affect Osmolality

- Urine
  - Increasing Osm
    - Fluid volume deficit
    - SIADH
    - Heart Failure
    - Acidosis

Fluid Volume Shifts

- Fluid normally shifts between intracellular and extracellular compartments to maintain equilibrium between spaces
- Fluid not lost from body but not available for use in either compartment — considered third-space fluid shift ("third-spacing")
- Enters serous cavities (transcellular)
Causes of Third-Spacing

- Burns
- Peritonitis
- Bowel obstruction
- Massive bleeding into joint or cavity
- Liver or renal failure
- Lowered plasma proteins
- Increased capillary permeability
- Lymphatic blockage

Assessment of Third-Spacing

- More difficult – fluid sequestered in deeper structures
- **Signs/Symptoms**
  - Decreased urine output with adequate intake
  - Increased HR
  - Decreased BP, CVP
  - Increased weight
  - Pitting edema, ascites

The Pressures

- Osmotic Pressure-
- Oncotic Pressure
- Hydrostatic Pressure
Edema

- Accumulation of water in the interstitial space due to disruption in the forces and mechanisms that normally keep net filtration at zero

Fluid Volume Excess (FVE)

- Hypervolemia
- Isotonic expansion of ECF caused by abnormal retention of water and sodium
- Fluid moves out of ECF into cells and cells swell

Causes

- Cardiovascular – Heart failure
- Urinary – Renal failure
- Hepatic – Liver failure, cirrhosis
- Other – Cancer, thrombus, PVD, drug therapy (i.e., corticosteroids), high sodium intake, protein malnutrition


**Signs/Symptoms**

- Physical assessment
  - Weight gain
  - Distended neck veins
  - Periorbital edema, pitting edema
  - Adventitious lung sounds (mainly crackles)
  - Dyspnea
  - Mental status changes
  - Generalized or dependent edema

**Intravenous Therapy**

**Transfusion Reactions**

- Transfusion reactions occur when there is a discrepancy between the blood type of the patient and the type of the blood being transfused.
  - Fever
  - Chills
  - Hives
  - Hypotension
  - Palpitations
  - Tachycardia
  - Flushing of the skin
  - Headache
  - Loss of consciousness
  - Nausea
  - Vomiting
  - Shortness of breath
Treatment of Transfusion Reactions (1 of 2)

- IMMEDIATELY stop the transfusion.
- Save the substance being transfused.
- Rapid IV infusion.
- Assess the patient’s mental status.
- Administer oxygen.
- Contact medical direction.
- Be prepared to administer mannitol, diphenhydramine, or furosemide.

Fluid Replacement

<table>
<thead>
<tr>
<th>Resuscitation Fluids</th>
<th>Resuscitation Fluid Used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diagnosis</strong></td>
<td><strong>1st Choice</strong></td>
</tr>
<tr>
<td>Hemorrhagic Shock</td>
<td>Whole Blood</td>
</tr>
<tr>
<td>Shock Due to Plasma Loss (S-Hot)</td>
<td>Plasma substitute</td>
</tr>
<tr>
<td>Dehydration</td>
<td>Lactated Ringer’s or normal saline</td>
</tr>
</tbody>
</table>

Intravenous Fluids
Hemoglobin-Based Oxygen-Carrying Solutions (HBOCs)

- Commonly referred to as “blood substitutes”
  - Compatible with all blood types
  - Do not require blood typing, testing, or cross-matching

Colloids

- Colloids remain in intravascular spaces for an extended period of time and have oncotic force.
  - Plasma protein fraction (Plasmanate)
  - Salt-poor albumin
  - Dextran
  - Hetastarch (Hespan)

Crystalloids

- Crystalloid solutions are the primary compounds used in prehospital care.
  - Isotonic solutions
  - Hypertonic solutions
  - Hypotonic solutions
The effects of hypertonic, isotonic, and hypotonic solutions on red blood cells

Most Commonly Used Solutions in Prehospital Care

<table>
<thead>
<tr>
<th>Solution</th>
<th>Tonicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactated Ringer</td>
<td>Isotonic</td>
</tr>
<tr>
<td>Normal saline</td>
<td>Isotonic</td>
</tr>
<tr>
<td>D5W</td>
<td>Hypotonic</td>
</tr>
</tbody>
</table>

IV Fluid Replacement

- IV Fluid to manage fluid volume imbalances
- Isotonic fluids (approximate normal serum plasma)
  - Rapid ECF expansion needed
  - D₅W, NS, LR
**Crystalloid Composition**

Composition of common crystalloid solutions:

<table>
<thead>
<tr>
<th>Solution</th>
<th>Other Name</th>
<th>[Na⁺] (mmol/L)</th>
<th>[Cl⁻] (mmol/L)</th>
<th>Glucose (mmol/L)</th>
<th>Glucose (mg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5W</td>
<td>5% Dextrose</td>
<td>0</td>
<td>0</td>
<td>278</td>
<td>5000</td>
</tr>
<tr>
<td>Normal saline</td>
<td>0.9% NaCl</td>
<td>154</td>
<td>154</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ringer’s lactate</td>
<td>Lactated Ringer</td>
<td>130</td>
<td>109</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Effects of adding 1 liter of Fluid**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Change in ECF</th>
<th>Change in ICF</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5W</td>
<td>333 mL</td>
<td>667 mL</td>
</tr>
<tr>
<td>Normal saline</td>
<td>1000 mL</td>
<td>0 mL</td>
</tr>
<tr>
<td>Ringer’s lactate</td>
<td>900 mL</td>
<td>100 mL</td>
</tr>
</tbody>
</table>

**Acid-Base Derangements**
**Respiratory Acidosis**

Caused by abnormal retention of CO₂ from impaired ventilation due to problems occurring in the lungs or respiratory center of the brain.

\[
\text{Respiration} \rightarrow \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^-
\]

**Respiratory Alkalosis**

Caused by increased respiration and excessive elimination of CO₂. The CO₂ level is decreased and the pH is increased.

\[
\text{Respiration} \rightarrow \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^-
\]

**Metabolic Acidosis**

Results from the production of metabolic acids such as lactic acid. These acids consume bicarbonate ions. Can be the result of dehydration, diabetes, or medication usage.

\[
\text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2
\]
Compensation for metabolic acidosis begins with an increase in respirations.

Metabolic Alkalosis

The pH is increased and the CO\textsubscript{2} level is normal. It is usually caused by administration of diuretics, loss of chloride ions associated with prolonged vomiting, and overzealous administration of sodium bicarbonate.

\[ H^+ + HCO_3^- \rightarrow H_2CO_3 \rightarrow H_2O + \rightarrow CO_2 \]

Hypoperfusion
Hypoperfusion (shock) is inadequate perfusion of body tissues.

Progression of Shock

- Cellular Death
- Tissue Death
- Organ Death
- Organ System Death
- Organ Death
- Organism Death

The Pathophysiology of Hypoperfusion
Causes of Hypoperfusion (1 of 3)

- Inadequate pump
  - Inadequate preload
  - Inadequate cardiac contractile strength
  - Excessive afterload

Causes of Hypoperfusion (2 of 3)

- Inadequate fluid or volume
  - Hypovolemia

Causes of Hypoperfusion (3 of 3)

- Inadequate container
  - Dilated container without change in fluid volume (inadequate systemic vascular resistance)
  - Leak in the container
Shock at the Cellular Level

Shock causes vary; however, the ultimate outcome is impairment of cellular metabolism.

Impaired Use of Oxygen

When cells don't receive enough oxygen or cannot use it effectively, they change from aerobic to anaerobic metabolism.

Compensation and Decompensation

Usually the body is able to compensate for any changes. However, when the various compensatory mechanisms fail, shock develops and may progress.
Compensation Mechanisms
- Heart Rate
- Vasoconstriction
- Blood Pressure
- Respiratory

Stages of Shock
- Compensated Shock?
- What occurs?
- Which part of the nervous system is stimulated?

Stages of Shock
- Decompensated Shock?
- What occurs?
- What interventions? The body or you as a paramedic?
Stages of Shock

- Irreversible Shock?
- Critical factors?
- What can you do?

www.stagesofshock.com

Types of Shock

- Cardiogenic
- Hypovolemic
- Neurogenic
- Anaphylactic
- Septic
Cardiogenic Shock

- The heart loses its ability to supply all body parts with blood.
- Usually the result of left ventricular failure secondary to acute myocardial infarction or CHF.
- Many patients will have normal blood pressures.

Cardiogenic Shock Evaluation

- The major difference between cardiogenic shock and other types of shock is the presence of pulmonary edema causing:
  - Difficulty breathing.
  - As fluid levels rise, wheezes or crackles (rales) may be heard.
  - There may be a productive cough with white or pink-tinged foamy sputum.
  - Cyanosis, altered mentation, and oliguria.

Cardiogenic Shock Treatment (1 of 2)

- Assure an open airway.
- Administer oxygen.
- Assist ventilations as necessary.
- Keep the patient warm.
Cardiogenic Shock
Treatment (2 of 2)
- Elevate the patient’s head and shoulders.
- Establish IV access with minimal fluid administration.
- Monitor the heart rate.
- Dopamine or dobutamine may be administered.

Hypovolemic Shock
- Shock due to loss of intravascular fluid
  - Internal or external hemorrhage
  - Trauma
  - Long bones or open fractures
  - Dehydration
  - Plasma loss from burns
  - Excessive sweating
  - Diabetic ketoacidosis with resultant osmotic diuresis

Fluid volume deficit
- What happens
  - Output > Intake -> Water extracted from ECF
    - ECF hypertonic (water moves out of cell -> cell dehydration) + osmotic pressure increased (stimulates thirst preceptor in hypothalamus)
    - ICF hypotonic with decreased osmotic pressure -> posterior pituitary secretes more ADH
    - Decreased ECF volume -> adrenal glands secrete aldosterone
Signs and Symptoms

- Decreased skin turgor
- Oliguria-low urine output
- Concentrated urine
- Weak, rapid pulse
- Capillary filling time elongated
- Decreased BP
- Increased pulse
- Sensations of thirst, weakness, dizziness, muscle cramps

Hypovolemic Shock Evaluation (1 of 2)

- Altered level of consciousness.
- Pale, cool, and clammy skin.
- Blood pressure may be normal, then fall.

Hypovolemic Shock Evaluation (2 of 2)

- Pulse may be normal then become rapid, finally slowing and disappearing.
- Urination decreases.
- Cardiac dysrhythmias may occur.
Hypovolemic Shock Treatment

- Maintain airway control.
- Control severe bleeding.
- Keep the patient warm.
- Administer a bolus of crystalloid solution for fluid replacement.
  - Nontrauma or no blood loss
  - Bolus crystalloid or colloid solutions
  - Trauma or blood loss
    - "Permissive hypotension" – SBP of 70-85 mmHg
- PASG if part of local protocol.

Effects of adding 1 liter of Fluid

<table>
<thead>
<tr>
<th>Solution</th>
<th>Change in ECF</th>
<th>Change in ICF</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5W</td>
<td>333 mL</td>
<td>667 mL</td>
</tr>
<tr>
<td>Normal saline</td>
<td>1000 mL</td>
<td>0 mL</td>
</tr>
<tr>
<td>Ringer's lactate</td>
<td>900 mL</td>
<td>100 mL</td>
</tr>
</tbody>
</table>

Significant Points

- Dehydration – one of most common disturbances in infants and children
- Additional S/S
  - Sunken eyeballs
  - Depressed fontanels
  - Significant wt loss
Neurogenic/Obstructive Shock

- Results from injury to brain or spinal cord causing an interruption of nerve impulses to the arteries.
- The arteries dilate, causing relative hypovolemia.
- Sympathetic impulses to the adrenal glands are lost, preventing the release of catecholamines with their compensatory effects.

Neurogenic Shock Evaluation

- Warm, dry, and red skin
- Low blood pressure
- Slow pulse

Neurogenic Shock Treatment

- Maintain airway control.
- Maintain body temperature.
- Immobilization of the patient.
- Consider other possible causes of shock.
- IV access and medications that increase peripheral vascular resistance.
Anaphylactic Shock

- A severe immune response to a foreign substance.
- Signs and symptoms most often occur within a minute, but can take up to an hour.
- The most rapid reactions are in response to injected substances
  - Penicillin injections
  - Bees, wasps, and hornets

Evaluation

Cardiovascular system
- Vasodilation, increased heart rate, and decreased blood pressure

Gastrointestinal system
- Nausea, vomiting, abdominal cramping, and diarrhea

Nervous system
- Altered mental status, dizziness, headache, seizures, and tearing

Treatment

- Airway protection; may include endotracheal intubation.
- Establish an IV of crystalloid solution.
- Pharmacological intervention
  - Epinephrine, antihistamines, corticosteroids, vasopressors, and inhaled beta-agonists
Septic Shock

- An infection that enters the bloodstream and is carried throughout the body.
- The toxins released overcome the compensatory mechanisms.
- Can cause the dysfunction of an organ system or result in multiple organ dysfunction syndrome.

Septic Shock Evaluation

- The signs and symptoms are progressive.
  - Increased to low blood pressure
  - High fever, no fever, or hypothermic
  - Skin flushed, pale, or cyanotic
  - Difficulty breathing and altered lung sounds
  - Altered mental status

Septic Shock Treatment

- Maintain airway control.
- Establish an IV of crystalloid solution.
- Administer dopamine to support blood pressure.
- Monitor heart rhythm.
MODS Stages

Primary MODS

- Organ damage results directly from a specific cause such as ischemia or inadequate tissue perfusion from shock, trauma, or major surgery.
- Stress and inflammatory responses may be mild and undetectable.
- During this response, neutrophils, macrophages, and mast cells are thought to be "primed" by cytokines.

Secondary MODS

- The next time there is an injury, ischemia, or infection, the primed cells are activated, producing an exaggerated inflammatory response.
- The inflammatory response enters a self-perpetuating cycle causing damage and vasodilation.
- An exaggerated neuroendocrine response is triggered causing further damage.
MODS 24 Hours after Resuscitation
- Low grade fever
- Tachycardia
- Dyspnea
- Altered mental status
- General hypermetabolic, hyperdynamic state

MODS within 24 to 72 Hours
- Pulmonary failure begins.

MODS within 7 to 10 Days
- Hepatic failure begins.
- Intestinal failure begins.
- Renal failure begins.
MODS within 14 to 21 Days
- Renal and hepatic failure intensify.
- Gastrointestinal collapse.
- Immune system collapse.

MODS after 21 Days
- Hematological failure begins.
- Myocardial failure begins.
- Altered mental status resulting from encephalopathy.
- Death.

Pathogenesis of Shock