ADVANCED ASSESSMENT
Fluids & Electrolytes
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References – Emergency Medicine
Body Is Made Up Of

- Fluid
- Salts
- Solids (organs and tissues)
- Fat (carbon and hydrogen = minimal water)
Fluids and Electrolytes

- **Body Fluids**
  - Mainly water
  - Found in all body compartments

- **Electrolytes**
  - Acids, Bases and Salts
  - Substances that dissolve in water, conduct electricity and dissociate into ions
Body Water Volume

- Approx. 42 litres
  - 28 intracellular
  - 10.5 interstitial
  - 3.5 intravascular
Water Distribution

- 60% of normal adult male
- 57% adult female
- 70% 1 year old
- 80% newborn (greater volume extracellular)
Distribution

- Plasma: 8%
- Interstitial (intercellular) fluid: 25%
- Extracellular fluid (ECF): 33%
- Intracellular fluid (ICF): 66%

Enlarged detail

Capillary
Functions - Water

- Building of cell protoplasm
- Protects body tissues such as spinal cord and brain
- Maintain normal osmotic pressure in the body
- Major constituent of blood
- Regulation of body temperature
Blood

- Made up of Liquid and Formed Elements
Liquid (Plasma 55%)

- 92 % Water
- 8 % Proteins
- Albumin (main plasma colloid)
- Fibrinogen (clotting)
- Globulin (alpha, beta, gamma)
- Play a role in immunity
FORMED ELEMENTS 45%
Red Blood Cells

- 5.2 -> 5.4 million/ml (male)
- 4.5 million/ml (female)
- Most abundant (95% of formed elements)
- Body makes 2.5 million per second, each last approximately one hundred and twenty days
- Primarily responsible for tissue oxygenation
- Waste cells broken down by spleen
Body Is Made Up Of

- Fluid
- Salts-dissolve in water to form electrolyte solutions
- Solids (organs and tissues)
- Fat (carbon and hydrogen = minimal water)
Electrolytes

- A solution that contains ions and is capable of conducting an electrical charge
- Commonly these solutions are made up of cations and anions.

Cation - an ion with a positive charge
Anion – an ion with a negative charge
Extracellular Cations and Anions

- **Cation**
  - Sodium Na+
  - Calcium Ca++

- **Anions**
  - Chloride Cl-
  - Bicarbonate HCO₃-
  - Biphosphate 2PO₄-
  - Sulfate SO₄-
Intracellular Cations and Anions

- **Cations**
  - Potassium K+
  - Calcium Ca++
  - Magnesium Mg+

- **Anions**
  - Biphosphate 2PO4-
  - Protein
Cell Membranes

* Cell membranes are made up of lipid bilayers, they are not normally permeable to ions.
* Ions must get into the cell through ion channels
* Normally they will do so through a process known as diffusion
Diffusion: is a net transport of atoms or molecules caused by their random thermal motion in an attempt to equalize concentration differences (DC).
Diffusion of water through a semi permeable membrane

- from a higher water concentration to a lower water concentration
- From lower solute concentration to a higher solute concentration
Osmotic Pressure

- Osmotic Pressure (p) is the hydrostatic pressure, that must be applied to the side of a semi permeable membrane with higher solute concentration in order to stop the water flux, so that the net water flux is zero.
Oncotic Pressure

- The Osmotic Pressure exerted in the vascular compartment due to the presence of plasma proteins
  - Albumin
  - Blood constituents
Oncotic Pressure

**Hydrostatic Pressure**

**Albumin-creates osmotic pressure**
Active Transport

- Movement of molecules and ions against their concentration gradients
  - From lower to higher concentrations
- Requires ATP
- 2 Types of Active Transport:
  - Primary (uses ATP)
  - Secondary (uses electrochemical gradient)
Active Transport

Phosphorylated conformation Y of carrier

Dephosphorylated conformation X of carrier

Molecule to be transported

Concentration gradient

(ECF) (High)

(ICE) (Low)

Direction of transport

ADP

P

ATP

2014 Version

OBHG Education Subcommittee
Na⁺ / K⁺ Pump

When open to the ECF, the carrier drops off Na⁺ on its high-concentration side and picks up K⁺ from its low-concentration side.

Phosphorylated conformation Y of Na⁺-K⁺ pump has high affinity for Na⁺ and low affinity for K⁺ when exposed to ICF.

Dephosphorylated conformation X of Na⁺-K⁺ pump has high affinity for K⁺ and low affinity for Na⁺ when exposed to ECF.

When open to the ICF, the carrier picks up Na⁺ from its low-concentration side and drops off K⁺ on its high-concentration side.

○ = Sodium (Na⁺)  ▲ = Potassium (K⁺)
Tonicity

- The effect of a solution on the osmotic movement of H2O
  - Isotonic
  - Hypotonic
  - Hypertonic
Tonicity

- **Isotonic:**
  - Equal tension to plasma
  - RBCs will not gain or lose H20
  - Normal Saline or Physiological Saline
    - 0.9% NaCl
    - D5W (Dextrose 5% in Water)
    - 5% Glucose
  - Lactated Ringers
    - Glucose, lactic acid, salt
Tonicity

- **Hypotonic:**
  - Osmotically active solutes in a lower osmolality and osmotic pressure than plasma
  - RBC will gain water

  - Water
  - 0.5% saline
Tonicity

- **Hypertonic:**
  - Osmotically active solutes in a higher osmolality and osmotic pressure than plasma
  - RBC will lose water

- D50
- Sea Water
- Dextran
ANATOMY AND PHYSIOLOGY
Veins vs. Arteries

- Low pressure
- Thinner than arteries
- Capacitance system (70% blood volume)
- Valves (legs have large amount of valves)
- No elasticity
- Near Surface
- Dark red blood

- High pressure
- Thick
- Internal and external elastic membrane has property of recoil which propels blood along vessel
- Resistance to flow relative to lumen size
- Deep
- Bright red blood
Blood Flow Through the Body

1) Arteries ---> 2) Arterioles --->
3) Pre Capillary Sphincters ---> 4) Capillaries --->
5) Post Capillary Sphincters ---> 6) Venules --->
7) Veins
Nutrient Exchange in the Capillary

**Hydrostatic Pressure** = Force water exerts on vasculature

Colloidal Osmotic Pressure = Drawing or pull of water due to colloids in solution (protein, albumin, glucose)
Tissue cells

Arterial end of capillary

Blood flow

Interstitial fluid

Venous end of capillary

Key to pressure values:

$\text{HP}_c$ at arterial end = 35 mm Hg
$\text{HP}_c$ at venous end = 17 mm Hg

$\text{HP}_{if} = 0$ mm Hg
$\text{OP}_{if} = 1$ mm Hg
$\text{OP}_c = 26$ mm Hg
Oncotic Pressure

Albumin creates osmotic pressure

Hydrostatic Pressure
KIDNEY & URINE PRODUCTION
Fluid Balance

- Daily Intake = Daily Loss
  - Intake
    - Drinking and eating
  - Loss
    - Urine
    - Skin
    - Lungs
    - GI Track
Fluid Balance

2500 ml/day = in
2500 ml/day = out

- Insensible losses (water loss you are unaware of)
  - Sweat
  - Respirations
Abnormal Fluid Loss Can Result From

- Disorders that affect the kidneys: ex diabetes mellitus, decrease in anti diuretic hormone (ADHD)
- Water loss from lungs and skin in conditions such as fever and increased respiratory rate
- Skin injuries (burns) third space shift
- G.I Tract (vomiting and diarrhea)
Kidney

- Removes waste products from blood
- Maintains constant fluid volume and composition
- 2 Kidneys shaped like a kidney bean
- Either side of the vertebral column (superior portion protected by rib cage)
- Protected by fibrous renal capsule (thick adipose tissue)
- Only place in body where blood is filled and drained by an arteriole
Outer layer of Kidney

>Cortex

Inner layer

>Medulla
Basic Functional Unit of the Kidney

NEPHRON
More Than 2 Million Per Kidney
Forms Urine
Urine Production

- Blood from Glomerulus passes into Bowman’s capsule (GFR= 180 l per day, 125ml per minute) producing 1-2 liters of urine/day
- Proximal Convoluted Tubule
- Loop of Henle
- Distal Convoluted Tubule
- Collecting Tubule
- During this process many substances in the filtrate are reabsorbed by the blood capillaries around the tubules (water, glucose, nutrients, sodium, other ions)
- Waste secreted as urine (contains hydrogen, potassium, ammonia)
Why is Holding onto Sodium so Important?
Sodium - Na +

- Major extracellular cation
- Maintains extracellular fluid volume and osmotic pressure
- Ph regulator
- Transmission of nerve and muscle impulses
- Regulates cell membrane permeability
Hyponatremia

- **Cause:**
  - Volume depletion
  - Hyperglycemia
  - Over secretion of ADH
  - Kidney disease/failure
  - Edema

- **Signs and Symptoms**
  - Parallel with S&S of fluid volume deficit
  - Loss of skin turgor
  - Tachycardia/hypotension
  - Lethargy/Muscle weakness
  - Muscle cramps
  - Confusion
Hypernatremia

- **Cause:**
  - Lack of water
  - Fluid loss exceeds Na+ loss
  - Salt poisoning

- **Signs and Symptoms**
  - Extreme muscle irritability
  - Dry mucous membranes
  - Flushed skin
  - Thirst
  - Increased Temperature
  - Decreased urine output
Potassium – K+

- Major intracellular cation
- Regulates neuromuscular irritability (especially cardiac)
- Necessary for transmission of electrochemical impulses along nerves and within muscle cells
- Maintains fluid volume within the cell
- Controls hydrogen ion concentration (regulates Ph)
Hypokalemia

- **Cause:**
  - Decreased K+ intake (not eating, lots of I.V fluid without K+)
  - Excess vomiting, gastric suction, diarrhea
  - Diuretic treatment (thiazides, Lasix)
  - Kidney Disease (unable to reabsorb K+)

- **Signs and Symptoms:**
  - Muscle weakness, cramps, flaccid paralysis
  - Fatigue, confusion
  - Dysrhythmias, heart block, flat T wave, prolonged Q-T interval
  - Respiratory/Cardiac arrest
Hyperkalemia

- **Cause:**
  - Respiratory or Metabolic Acidosis
  - Renal failure
  - Crush injuries
  - Excess to rapid K+ administration

- **Signs and Symptoms:**
  - Weakness to flaccid paralysis
  - Numbness, tingling in face, tongue, hands, feet
  - Increased G.I tone (diarrhea)
  - Heart Arrhythmias
  - Tall peaked T waves
  - Widened QRS
Magnesium Mg+

- Mostly Intracellular
- Plays role in neuromuscular function (excess Mg+ sedates muscles, used as an anti seizure medication for eclampsia)
- Provides energy for Na+/K+ pump
- Hypomagnesemia: often caused by poor food intake, alcoholics
- Causes
  - Polymorphic Ventricular Tachycardia
- Tx
  - Magnesium Sulphate
Calcium Ca+

- Most abundant cation in the body: 99% found in bones and teeth, 1% in plasma
- Muscle contraction
- Formation of bones and teeth
- Blood coagulation
- Control of neuromuscular activity
Bicarbonate  HCO3-

- Major part of blood buffer system
- Regulates Ph
PH REGULATION
PH Regulation

PH: NEGATIVE LOG OF HYDROGEN ION

CONCENTRATION \(-\log[H^+]\)

Free hydrogen ion concentration in the body is low, roughly \(0.000001\) mol/l (expressed mathematically \(10^{-7}\))

Because numbers are so cumbersome the 10 was dropped and Ph is expressed from range of 1 to 14 with 7 being neutral (LESS THAN 7 CONSIDERED ACIDIC AND GREATER THAN 7 BEING BASIC)
An increase in hydrogen ion concentration makes the solution more acidic (Ph less than 7)

- A decrease in the amount of hydrogen ion concentration makes the solution more alkaline (Ph greater than 7)
- Normal Ph is between 7.35 and 7.45 so anything less than 7.35 is considered to be acidic
Bicarbonate buffer system.

Death  Acidosis  Alkalosis  Death

6.9  7.35  7.45  8.0

H₂CO₃  HCO₃⁻
Importance of Acid Base Balance

- Normal body function can only occur if the composition of body cells and their surrounding environment are kept relatively constant.
- The body must maintain a constant regulation of fluid and electrolytes and acid base balance.
- Disturbances of acid base balance lead to cellular dysfunction and death.
- Ph less than 6.8 and greater than 7.9 = DEATH.
- Acid Base Balance refers to the balance of the hydrogen ion concentration in the body fluids
- The body produces large amounts of acids which are by-products of cellular metabolism
- If acids were allowed to accumulate death would occur
- The body must have mechanisms that can minimize changes in pH
Body Has Two Distinct Tasks

- Prevention of Ph changes in the blood while transporting these hydrogen ions to the organs where they will be excreted
- Elimination of excess hydrogen ions from the body
MECHANISMS OF PH REGULATION AND H+ ION EXCRETION
pH Regulators

- Physiological
- Respiratory
- Renal
Physiological

Acid base buffer is a chemical solution which prevents an excessive change in pH (H+ ion concentration)

- Buffers in the body are either a base or an acid
- If excess base is added to the solution the weak acid portion of a buffer reacts with it to neutralize it
- If excess acid is added to the solution the alkali salt (base) reacts to neutralize it
Physiological

- Keep blood pH changes to a minimum (between 7.35 and 7.45) while transporting hydrogen ions to where they will be excreted
- Act immediately in response to an upset in the balance of hydrogen ions in the body fluids

1. Bicarbonate/Carbonic Acid Buffer System (Major buffer system)
2. Phosphate buffer system
3. Protein buffer system
4. Hemoglobin buffer system
Glucose + Oxygen = 38 ATP + 6 CO2 + 6 H2O
As seen above in Krebs Cycle. CO2 and Water is the major bi-product of cell metabolism

In the blood stream Carbon Dioxide and Water form Carbonic Acid (inside red blood cell with help from carbonic anhydrase)

\[
\begin{align*}
\text{CO2 + H2O} & \quad \rightarrow \quad \text{H2CO3} \\
\text{H+ --- HCO3} & \quad \rightarrow \quad \leftarrow
\end{align*}
\]

Carbonic Acid Dissociates into Hydrogen (buffered by chemical buffers) and bicarbonate (while being transported to the lungs)
At the Lungs reaction switches to the Left, CO2 is reformed and blown off. Water dissipates into general water pool.
The Lungs are responsible for the regulation of the levels of **VOLATILE ACIDS** (ones that can be blown off at the lungs CO2).

AS CO2 LEVELS INCREASE SO DO HYDROGEN LEVELS. LIKEWISE IF CO2 LEVELS DECREASE SO DO HYDROGENS LEVELS.
With **HYPERVENTILATION CO2** is blown off which ultimately decreases hydrogen ion concentration (increase pH)

With **HYPOVENTILATION CO2** is retained which increases hydrogen ion concentration (decrease in pH)

**LUNGS WORKING ALONE CAN ADJUST HYDROGEN LEVELS WITHIN SECONDS (RAPID)**

**GETS PH WITHIN NORMAL RANGE BUT CANNOT FINE TUNE IT (AROUND 7.2 TO 7.3)**
Responsible for regulation of non volatile or fixed acids (ones that can’t be breathed off) lactic acid, ketone bodies, phosphoric acid and sulfuric acid breakdown into H+ which must be excreted by the kidneys.

Whenever an imbalance of hydrogen occurs the kidney will adjust the secretion or absorption of acid (H+) or base (HCO₃⁻).
Renal System

- If the body becomes too acidic the kidney retains HCO3 and excretes H+
- If the body becomes too alkaline the kidney excretes HCO3 and retains H+ ions
- Slow system but fine tunes pH between 7.35 and 7.45
Acid Base Disturbances

- Respiratory Acidosis
Respiratory Acidosis (Retention of CO\textsubscript{2})

- pH less than 7.35
- Failure of lungs to blow off CO\textsubscript{2} which ultimately increases hydrogen ion concentration
- Caused by any pathology that decreases ventilation (lung diseases, drugs that decrease respiratory drive (narcotics, benzodiazepines)
- Kidneys will try to compensate by retaining HCO\textsubscript{3} and excreting H+
Acid Base Disturbances

- Respiratory Alkalosis

![Diagram showing respiratory alkalosis with pH values and chemical reactions involving CO₂ and H₂CO₃ → HCO₃⁻]
Respiratory Alkalosis

- pH greater than 7.45
- Lungs are blowing off excess CO2 ultimately decreasing hydrogen ion concentration
- Pathologies that increase ventilation (fever, voluntary hyperventilation)
- Kidney will try to compensate by excreting HCO3 and retaining H+
Acid Base Disturbances

- Metabolic Acidosis
Metabolic Acidosis

- pH less than 7.35
- Caused by an excess of non volatile acids in blood or a loss of HCO3 in the blood
- Causes: ketone production in uncontrolled diabetics, renal failure, severe diarrhea (G.I. loss of bicarbonate) aspirin overdose (late)
- Lungs compensate by hyperventilation (blowing off CO2)
Acid Base Disturbances

- Metabolic Alkalosis
Metabolic Alkalosis

- pH greater than 7.45
- Caused by a decrease in non volatile acids or an increase in HCO3 in the blood
- Excess HCO3 administration (cardiac arrest), prolonged vomiting (loss of acid)
Well Done!

Ontario Base Hospital Group
Self-directed Education Program