Unit 2 Lecture 7

WATER BALANCE, ACID-BASE BALANCE

In order for the body to function properly, the conditions in the internal environment must be maintained at relatively constant levels. In order to have a water balance, the water loss must be balanced by the water gained. Water is gained by drinking, eating, and by the metabolism of energy stores, while water can be lost through urine, sweating, lungs, and feces.

Water Balance – Regulation

Regulating the amount of water in the body is one of the main functions of the kidneys. It is very important to realize that the kidneys *do not* produce water. They can only "recycle" or reabsorb the water that is in the filtrate before it goes to the bladder. Water balance by the kidneys is regulated by **antidiuretic hormone** (**ADH**). ADH is produced in the hypothalamus of the brain and is released from the posterior pituitary. **Osmoreceptors** are located in the hypothalamus of the brain and respond to changes in body fluid concentrations. Changes in fluid concentration can cause a cell to shrink or swell. Too much water (**overhydration**) or too little water (**dehydration**) can cause changes in fluid concentrations.

Fluid Compartments & Fluid Balance

In general, fluids comprise about 60% of body weight. Two-thirds of the fluids are intracellular fluids and one-third is extracellular fluid. Eighty percent of the extracellular fluid is called interstitial fluid. Twenty percent is plasma. Because water moves easily through plasma membranes, homeostatic mechanisms of fluids keeps volumes in each compartment stable - usually by osmosis. Fluids also contain solutes; most of which are electrolytes. The movement of body fluids between compartments is dependent on hydrostatic and osmotic pressure. Blood hydrostatic pressure, interstitial fluid hydrostatic pressure, blood colloid osmotic pressure, and interstitial fluid colloid osmotic pressure all play a role. The differences that move fluid out of plasma and those that push it back into the plasma equals the net filtration pressure. Exchange between interstitial fluid and intracellular fluid is usually caused by an imbalance of sodium or potassium ion concentration. Na^+ level are controlled by secretion of aldosterone, ADH, and ANP. Fluid imbalances can lead to over hydration, water intoxication, and circulatory shock.

Water is the largest single component of body. Males have move than females and the percentage of water is less in fatter people than thin people because fat is water free. The water we ingest is preformed water. Metabolic water is produced during anabolic procedures. Normally water loss in the body equals water gain. Dehydration stimulates thirst in three ways;

decrease in saliva causes dryness in the mouth which sends a stimulus to the hypothalamus, secondly, an increase in blood osmotic pressure, and thirdly a decrease in blood volume causes a decrease in blood pressure which stimulates release of renin by the JGA. As a result of thirst, fluid ingested balances the output. The regulation of fluid output (loss) is adjusted by ADH, aldosterone and ANP. Abnormal factors influencing fluid loss are hypertension, hyperventilation, fever, perspiration.

ELECTROLYTE BALANCE

Electrolytes are chemicals that dissolve in body fluids and that disassociate into anions and cations. Most are inorganic compounds and include acids, bases, and salts. Electrolytes have a greater effect on osmosis than non-electrolytes. The function of electrolytes is to control osmosis of H_2O between compartments, help maintain acid-base balance, and carry electrical current. Electrolytes are the essential minerals: Na^+, K^+, HCO_3^-, and Cl^-.

Sodium is the primary extracellular cation and chloride is the primary extracellular anion. Principle intracellular anions are phosphate and proteins and potassium is the primary cation. Sodium has a major role in fluid balance because it determines the total body water and distribution of water among fluid compartments. Sodium's influence in electrolyte balance is just as important. Sodium gradients across plasma membrane provide the potential energy that is tapped to co-transport other solutes such as glucose. Sodium levels in blood are controlled by aldosterone, ADH, and ANP. The Na^+-K^+ pump is an important mechanism for generating body heat.

Chloride is the major extracellular anion and is indirectly under control of aldosterone. Chloride plays a role in osmolarity, osmosis and formation of HCl. Potassium is the major intracellular cation. Abnormally high levels will induce atrial fibrillation. Potassium is involved in muscle contractions and impulse conduction. Calcium is the most abundant ion in the body and is stored in bones and teeth. It functions in blood coagulation, neurotransmitter, and release of muscle contractions. Phosphates are intracellular anions. They are a structural component of teeth and bones and are necessary for DNA and RNA synthesis. Magnesium is the second most common intracellular electrolyte. It activates enzymes involved in metabolism of carbohydrates and proteins.

ACID BASE BALANCE

The normal pH of the body is 7.35-7.45. Acid-base balance is maintained by controlling the H^+ concentration of body fluids; especially in extracellular fluid. The buffer systems, the exhalation of CO_2, and renal secretion of H^+ eliminate excess H^+. Buffer systems act quickly to bind H^+ and prevent rapid changes by changing strong acids or strong bases into weak acids or weak bases.

- The **carbonic acid-bicarbonate buffer system** maintains blood pH. You can see that the following equation is a reversible reaction depending on if the there is too much acid or base in the blood. This system in works well in the lungs and kidneys.

$$CO_2 + H_2O \leftrightarrow H2CO3 \leftrightarrow HCO_3^- + H^+$$

- The **phosphate buffer system** regulates fluid in the cytosol much in the same way as the carbonic acid-bicarbonate system. This system functions within the cell and in the renal tubules.

$$H_2PO_4^- \leftrightarrow HPO_4^{2-} + H^+$$

- The **protein buffer system** is found in body cells and plasma. It accounts for 3/4 of all chemical buffering in body fluids. This system works by either releasing H^+ from carboxyl groups on amino acids when pH begins to rise and thus lowering pH or by binding H^+ to amino groups of amino acids when pH falls too low thus raising pH.

Exhalation of CO_2 can regulate pH. An increase in exhalation of CO_2 (hyperventilation) will increase pH (making the blood more alkaline) whereas a decrease of exhalation of CO_2 (hypoventilation) will decrease pH (making the blood more acidic). The respiratory mechanism is a rapid process. Kidneys maintain pH by excreting H^+ in the urine and reabsorbing HCO_3^-, but this is a slow process that may take days.

ACID-BASE IMBALANCE

Acidosis is a blood pH <7.35. Acidosis causes depression in CNS and often causes coma. Alkalosis is a blood pH >7.45. When a person is in alkalosis they exhibit excitability of CNS, often convulsions. Compensation is the body's response to the acid-base imbalance.

Metabolic acidosis is acidosis due to the production of organic acids that exceed the rate of elimination (diabetes), a reduced excretion of acids (renal failure, tubular acidosis), or an excessive loss of bicarbonate (HCO_3^-) due to excessive loss of duodenal fluid (diarrhea). The compensatory mechanisms of the body is a stimulation of respiratory system producing hyperventilation which results in loss of CO_2 or if in the renal system, an increase excretion of acid and conservation of base, increase ammonia formation, and an increase reclamation of HCO_3^-.

Metabolic alkalosis is due to the administration of excess alkali ($NaHCO_3$), (such as citrate in transfused blood or oral antacids), an excessive loss of HCl after prolonged vomiting or a pyloric or intestinal obstruction, potassium depletion in Cushing's syndrome, renal HCO_3^- retention, prolonged administration of certain diuretics, or administration of laxatives or potassium poor IV fluids. Compensation by the body is the opposite in the above paragraph.

Respiratory acidosis (lungs not working) is due to a decreased elimination of CO_2 through the lungs (hypoventilation) or cardiac disease. Factors that directly depress the respiratory center in the brain include centrally acting drugs, CNS trauma or infection. Compensatory mechanisms include an increase pulmonary rate and depth of respiration if the defect is not in the respiratory center or renal compensation the same as in metabolic acidosis.

Respiratory alkalosis is due to a decreased CO_2 because of an increased rate or depth of respiration or both causing an excess elimination of CO_2. It is important for the treatment of the patient to determine whether the disorder is metabolic or respiratory. First determine the direction of the pH imbalance, acidosis or alkalosis. Then decide which variable ($HCO3^-$ or CO_2) changes in the same direction as pH. If $HCO3^-$ changes in the same direction (acid or alkaline) as pH, the problem is metabolic. If pCO_2 changes in the same direction (acid or alkaline) as pH, the problem is a respiratory origin. The variable which changes in the direction opposite that of the pH imbalance is compensatory. In the respiratory acidosis described below, increased renal $HCO3^-$ production opposes the acidosis and helps maintain homeostasis, reduced alveolar ventilation retains CO_2 which helps to oppose the alkalosis and maintain homeostasis.

Respiratory acidosis	Respiratory Alkalosis	Metabolic acidosis	Metabolic alkalosis
pH ⇩(acid)	pH ⇧ (alk.)	pH ⇩ (acid)	pH ⇧ (alk.)
pCO_2 ⇧ (acid)	pCO_2 ⇩ (alk.)	pCO_2 ⇩ (alk.)	pCO_2 ⇧ (acid)
HCO_3^- ⇧ (alk.)	HCO_3^- ⇩ (acid)	HCO_3^- ⇩ (acid)	HCO_3^- ⇧ (alk.)