McCance: Pathophysiology, 6th Edition

Chapter 03: The Cellular Environment: Fluids and Electrolytes, Acids and Bases

Key Points – Print

SUMMARY REVIEW

Distribution of Body Fluids

1. Body fluids are distributed among functional compartments and are classified as ICF or ECF.
2. The sum of all fluids is the TBW, which varies with age and amount of body fat.
3. Water moves between the ICF and ECF compartments principally by osmosis.
4. Water moves between the plasma and interstitial fluid by osmosis and hydrostatic pressure, which occur across the capillary membrane.
5. Movement across the capillary wall is called *net filtration* and is described according to the Starling law.

Alterations in Water Movement

1. Edema is a problem of fluid distribution that results in accumulation of fluid within the interstitial spaces.
2. Edema is caused by arterial dilation, venous or lymphatic obstruction, loss of plasma proteins, increased capillary permeability, and increased vascular volume.
3. The pathophysiologic process that leads to edema is related to an increase in forces favoring fluid filtration from the capillaries or lymphatic channels into the tissues.
4. Edema may be localized or generalized and usually is associated with weight gain, swelling and puffiness, tighter-fitting clothes and shoes, and limited movement of the affected area.

Sodium, Chloride, and Water Balance

1. Sodium and water balance are intimately related; chloride levels are generally proportional to changes in sodium levels.
2. Water balance is regulated by the sensation of thirst and by antidiuretic hormone, which is initiated by an increase in plasma osmolality or a decrease in circulating blood volume.
3. Sodium balance is regulated by aldosterone, which increases reabsorption of sodium by the distal tubule of the kidney.
4. Renin and angiotensin are enzymes that promote or inhibit secretion of aldosterone and thus regulate sodium and water balance.
5. Atrial natriuretic hormone is also involved in decreasing tubular resorption and promoting urinary excretion of sodium.

Alterations in Sodium, Chloride, and Water Balance

1. Alterations in water balance may be classified as isotonic, hypertonic, or hypotonic.
2. Isotonic alterations occur when changes in TBW are accompanied by proportional changes in electrolytes.
3. Hypertonic alterations develop when the osmolality of the ECF is elevated above normal, usually because of an increased concentration of ECF sodium or a deficit of ECF water.
4. Hypernatremia (sodium levels >147 mEq/L) may be caused by an acute increase in sodium or a loss of water.
5. Water deficit, or hypertonic dehydration, is rare but can be caused by lack of access to water, pure water losses, hyperventilation, arid climates, or increased renal clearance.
6. Hyperchloremia is caused by an excess of sodium or a deficit of bicarbonate.
7. Hypotonic alterations occur when the osmolality of the ECF is less than normal.
8. Hyponatremia (serum sodium concentration <135 mEq/L) usually causes movement of water into cells.
9. Hyponatremia may be caused by sodium loss, inadequate sodium intake, or dilution of the body’s sodium level.
10. Water excess is rare but can be caused by compulsive water drinking, decreased urine formation, or the syndrome of inappropriate secretion of ADH.
11. Hypochloremia is usually the result of hyponatremia or elevated bicarbonate concentrations.

Alterations in Potassium, Calcium, Phosphate, and Magnesium Balance

1. Potassium is the predominant ICF ion; it functions to regulate ICF osmolality, maintain the resting membrane potential, and deposit glycogen in liver and skeletal muscle cells.
2. Potassium balance is regulated by the kidney, by aldosterone and insulin secretion, and by changes in pH.
3. A mechanism known as *potassium adaptation* allows the body to accommodate slowly to increased levels of potassium intake.
4. Hypokalemia (serum potassium concentration <3.5 mEq/L) indicates loss of total body potassium, although ECF hypokalemia can develop without losses of total body potassium and plasma K^+ levels may be normal or elevated when total body potassium is depleted.
5. Hypokalemia may be caused by reduced potassium intake, increased ICF-to-ECF potassium concentration, loss of potassium from body stores, increased aldosterone secretion (e.g., caused by hypernatremia), and increased renal excretion.
6. Hyperkalemia (potassium levels >5.5 mEq/L) may be caused by increased potassium intake, a shift from ICF to ECF potassium, or decreased renal excretion.
7. Calcium is a necessary ion in the structure of bones and teeth, in blood clotting, in hormone secretion and the function of cell receptors, and in membrane stability.
8. Phosphate acts as a buffer in acid-base regulation and provides energy for muscle contraction.

9. Calcium and phosphate concentrations are rigidly controlled by PTH, vitamin D, and calcitonin.
10. Hypocalcemia (serum calcium concentration <8.5 mg/dl) is related to inadequate intestinal absorption, deposition of ionized calcium into bone or soft tissue, blood administration, or decreased PTH and vitamin D levels.
11. Hypercalcemia (serum calcium concentration >12 mg/dl) can be caused by a number of diseases, including hyperparathyroidism, bone metastases, sarcoidosis, and excess vitamin D.
12. Hypophosphatemia is usually caused by intestinal malabsorption and increased renal excretion of phosphate.
13. Hyperphosphatemia develops with acute or chronic renal failure with significant loss of glomerular filtration.
14. Magnesium is a major intracellular cation and is principally regulated by PTH.
15. Magnesium functions in enzymatic reactions and often interacts with calcium at the cellular level.
16. Hypomagnesemia (serum magnesium concentrations <1.5 mEq/L) may be caused by malabsorption syndromes.
17. Hypermagnesemia (serum magnesium concentrations >2.5 mEq/L) is rare and is usually caused by renal failure.

Acid-Base Balance

1. Hydrogen ions, which maintain membrane integrity and the speed of enzymatic reactions, must be concentrated within a narrow range if the body is to function normally.
2. Hydrogen ion concentration is expressed as pH, which represents the negative logarithm of hydrogen ions in solution.
3. Different body fluids have different pH values.
4. The renal and respiratory systems, together with the body's buffer systems, are the principal regulators of acid-base balance.
5. Buffers are substances that can absorb excessive acid or base without a significant change in pH.
6. Buffers exist as acid-base pairs; the principal plasma buffers are carbonic acid–bicarbonate, protein (hemoglobin), and phosphate.
7. Buffer pairs can associate and dissociate; the pK value is the pH at which a buffer pair is half dissociated.
8. The lungs and kidneys act to compensate for changes in pH by increasing or decreasing ventilation and by producing more acidic or more alkaline urine.
9. Correction is a process different from compensation; correction occurs when the values for both components of the buffer pair are returned to normal.

10. Acid-base imbalances are caused by changes in the concentration of H^+ in the blood; an increase causes acidosis, and a decrease causes alkalosis.
11. An abnormal increase or decrease in bicarbonate concentration causes metabolic acidosis or metabolic alkalosis; changes in the rate of alveolar ventilation produce respiratory acidosis or respiratory alkalosis.
12. Metabolic acidosis is caused by an increase in noncarbonic acids or loss of bicarbonate from the extracellular fluid.
13. Metabolic alkalosis occurs with an increase in bicarbonate usually caused by loss of metabolic acids from conditions such as vomiting, gastrointestinal suctioning, excessive bicarbonate intake, hyperaldosteronism, and diuretic therapy.
14. Respiratory acidosis occurs with a decrease of alveolar ventilation and an increase in levels of carbon dioxide, which in turn causes hypercapnia.
15. Respiratory alkalosis occurs with alveolar hyperventilation and excessive reduction of carbon dioxide, or hypocapnia.