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CHAPTER SIX

Caring for the Client with Disorders of Fluid and Electrolyte Balance and Acid/Base Balance

Terms you'll need to understand:

- ✓ Acidosis
- ✓ Active transport
- ✓ Alkalosis
- ✓ Diffusion
- ✓ Electrolyte
- ✓ Filtration
- ✓ pH

Nursing skills you'll need to master:

- ✓ Evaluating pH in clients

Basic Knowledge of Fluid and Electrolyte Balance

Although fluid and electrolyte balance and acid/base balance are separate entities, they are directly related to one another. For example, dehydration results in a decrease in the pH or metabolic acidosis, whereas overhydration results in an increase in the pH or metabolic alkalosis. To understand how this happens, let's review the basics of fluid movement across the cell membrane.

Fluid constantly moves in and out of the cell through a process known as *osmosis*. This fluid is compartmentalized into *intracellular* fluid (fluid that is within the cell) and *extracellular* fluid (fluid that is outside the cell). Two thirds of the body's fluid is intracellular. The remaining one third, or extracellular fluid, is divided between the intravascular and interstitial spaces.

Diffusion is the process whereby molecules move from an area of higher concentration to an area of lower concentration. Diffusion is affected by the amount and type of molecular particles. These molecular particles are removed from body fluid as they pass through semipermeable membranes in a process known as *filtration*.

Molecular particles can also pass from an area of lower concentration to one of higher concentration by a process known as *active transport*. Diffusion and active transport allow positively charged particles, called *cations*, and negatively charged particles, called *anions*, to pass in and out of the cell. These particles are also known as *electrolytes* because they are positively or negatively charged. As these cations and anions concentrate, they result in changes in the pH. Some examples of anions are bicarb (HCO_3–), chloride (Cl–), proteins, phosphates, and sulfates. Examples of cations are sodium (Na+), potassium (K+), magnesium (Mg++), and calcium (Ca++).

An *acid* is a substance that releases a hydrogen (H+) ion when dissolved in water, and a *base* is a substance that binds with a hydrogen ion when released in water. Therefore, when there is a decrease in bicarbonate hydrogen ions (HCO_3–) or an accumulation of carbonic acid, acidosis exists; when there is an increase in bicarbonate hydrogen ions (HCO_3–) or a loss of carbonic acid, alkalosis exists.

Within this chapter we will discuss how these factors affect acid/base balance (pH) and the regulation of electrolytes. You will also discover the disease processes that contribute to these alterations.

Regulation of pH and Its Effect on Fluid and Electrolytes

The body maintains its pH by keeping the ratio of HCO_3 (bicarb) to H_2CO_3 (carbonic acid) at a proportion of 20:1. HCO_3 or bicarbonate is base, whereas carbonic acid is acidic. This relationship constantly changes and is compensated for by the kidneys and lungs. The normal pH is 7.35–7.45, with the ideal pH being 7.40. If the carbonic acid concentration increases, acidosis occurs and the client's pH falls below 7.40. A pH below 7.35 is considered *uncompensated acidosis*. If the HCO_3 concentration increases, alkalosis occurs and the client's pH is above 7.40. A pH above 7.45 is considered *uncompensated alkalosis*.

How the Body Regulates pH

Two buffer systems in the body assist in regulating pH:

- **Kidneys**—By retaining or excreting $NaHCO_3$ (sodium bicarb) or by excreting acidic urine or alkaline urine. They also help by reabsorbing $NaHCO_3$– and secreting free H+ ions.
- **Lungs**—By retaining carbonic acid in the form of CO_2 (carbon dioxide) or by rapid respirations excreting CO_2.

When there is a problem with either the lungs' or kidneys' capability to compensate, an alteration in this balance results.

Let's discuss the alteration in acid/base balance as it affects electrolytes and pH.

Metabolic Acidosis

Metabolic acidosis results from a primary gain of carbonic acid or a loss of bicarbonate HCO_3 with a pH below 7.40.

Causes of Metabolic Acidosis

The following list are some causes of metabolic acidosis:

- **Certain disease states**—Disease states that create excessive metabolism of fats in the absence of usable carbohydrates, leading to the accumulation of ketoacids.
- **Diabetes mellitus**—Lack of usable insulin, leading to hyperglycemia and ketoacidosis.
- **Anorexia**—Leading to cell starvation.

- **Lactic acidosis**—Due to muscle and cell trauma, such as myocardial infarction.
- **Renal failure**—Leading to waste accumulation in the body and elevated levels of creatinine, BUN, uric acid, and ammonia. All these substances are acidic.
- **Diarrhea**—With a loss of HCO_3. This loss of HCO_3 and fluid leads to dehydration. When the client is dehydrated, acidosis is likely.
- **Excessive ingestion**—Ingestion of aspirin or other acids.
- **Overuse of diuretics**—Particularly nonpotassium-sparing diuretics.
- **Overwhelming systemic infections**—Also called *sepsis*. Overwhelming infections lead to cell death and nitrogenous waste accumulation.
- **Terminal stages of Addison's disease**—Adrenal insufficiency results in a loss of sodium and water. This leads to a decrease in blood pressure and hypovolemic shock.

Symptoms of Metabolic Acidosis

The following list highlights symptoms of metabolic acidosis that a nurse needs to be aware of for both the exam and for on-the-job observations:

- **Neurological**—Headache, lethargy, drowsiness, loss of consciousness, coma, death
- **Gastrointestinal**—Anorexia, nausea, vomiting, diarrhea, fruity breath
- **Respiratory**—Hyperventilation (due to stimulation of the hypothalamus)
- **Renal**—Polyuria and increased acid in the urine
- **Lab values**—Decreased pH, decreased $PaCO_2$, decreased serum CO_2, often increased potassium

Care of the Client with Metabolic Acidosis

Metabolic acidosis is rarely present without an underlying disease process. Treatment involves early diagnosis and treatment of the causative factors:

- **Monitor the potassium level (K+) and treat accordingly**—Because potassium (K+) is an intracellular cation, changes in potassium levels commonly occur with metabolic acidosis. The symptoms of hyperkalemia are malaise, generalized weakness, muscle irritability, flaccid paralysis, nausea, and diarrhea. If the potassium is excreted through the kidneys, hypokalemia can result. The symptoms of hypokalemia are diminished reflexes, weak pulse, depressed U waves on the ECG, shallow respirations, shortness of breath, and vomiting.

CAUTION

If administering potassium, always check renal function prior to administration. The kidney assists in regulating potassium. If the client has renal disease, a life-threatening hyperkalemia can result. Because potassium is bitter to taste, it should be administered with a juice such as orange juice, grape juice, tomato juice, or apple juice. Ascorbic acid also helps with absorption of the potassium. If administering an IV, always control infusion by using an IV pump or controller. An infusion that is too rapid can result in cardiac arrythymias. If giving IV, dilute the potassium with IV fluids to prevent hyperkalemia and burning of the vein.

- **Treat diabetes**—Treat with insulin for hyperglycemia; treat with glucose for hypoglycemia.
- **Treat hypovolemia**—Treat with a volume expander and blood transfusions and treat shock.
- **Treat renal failure**—Treatment includes dialysis or transplant and dietary modification. The diet for renal failure clients should control protein, sodium, and fluid. Supplemental calories and carbohydrates are suggested.
- **Treat lactic acidosis**—Treatment includes oxygen and $NaHCO_3$.
- **Treat Addison's disease**—Treatment includes cortisone preparations, a high sodium diet, and fluids for shock.

Nursing care of the client with metabolic acidosis includes frequent monitoring of vital signs and attention to the quality of pulses, and intake and output. Those with diabetes should be taught the importance of frequent blood glucose checks.

Respiratory Acidosis

Respiratory acidosis occurs when there is a decrease in the rate of ventilation to the amount of carbonic acid production. Hypoventilation leads to CO_2 accumulation and a pH value less than 7.35. Loss of the lungs as a buffer system causes the kidneys to compensate. In chronic respiratory acidosis, the kidneys attempt to compensate by retaining HCO_3.

Causes of Respiratory Acidosis

The following list highlights causes of respiratory acidosis you need to know. All these involve accumulation of carbonic acid (CO_2) and/or a lack of oxygenation:

- Over sedation or anesthesia.
- Head injury (particularly those affecting the respiratory center). This type of head injury leads to an increase in intracranial pressure and suppression of the respirations.
- Paralysis of the respiratory muscles (for example, Guillian-Barré, myasthenia gravis, or spinal cord injury).
- Upper airway obstruction.
- Acute lung conditions (such as pulmonary emboli, pulmonary edema, pneumonia, or atelectasis).
- Chronic obstructive lung disease.
- Prolonged overbreathing of CO_2.

CAUTION

When the client has been given general anesthesia followed by narcotic administration, there is a risk of narcotic overdose. The nurse should keep naloxone hydrochloride (Narcan) available as the antidote for narcotic overdose. Flumazenil (Romazicon) is the antidote for the client who is admitted with an overdose of benzodiazepines such as diazepam (Valium).

Symptoms of Respiratory Acidosis

The following list gives the symptoms of respiratory acidosis you need to know:

- **Neurological**—Dull sensorium, restlessness, apprehension, hypersomnolence, coma
- **Respiratory**—Initially increased respiratory rate, perspiration, increased heart rate; later, slow respirations and periods of apnea or Cheyne-Stokes respirations (breathing marked by periods of apnea lasting 10–60 seconds followed gradually by hyperventilation) with resulting cyanosis

CAUTION

Cyanosis is a late sign of hypoxia. Early signs are tachycardia and tachypnea.

Caring for the Client with Respiratory Acidosis

Care of the client with respiratory acidosis includes attention to signs of respiratory distress, maintaining a patent airway, encouraging fluids to thin secretions, and chest physiotherapy.

CAUTION

Percussion, vibration, and drainage should be done on arising, before meals, and prior to bedtime. Mouth care should be offered after percussion, vibration, and drainage. Cupped hands should be used to prevent trauma to the skin and bruising.

CAUTION

Effective toys for children with asthma or cystic fibrosis are toys such as horns, pinwheels, and whistles. These toys prolong the expiratory phase of respirations and help with CO_2 exhalation. The best sport is swimming.

Metabolic Alkalosis

Metabolic alkalosis results from a primary gain in HCO_3 or a loss of acid that results in a pH level above 7.45.

Causes of Metabolic Alkalosis

The following list highlights causes of metabolic alkalosis that you need to be aware of:

- Vomiting or nasogastric suction that may lead to loss of hydrochloric acid
- Fistulas high in the gastrointestinal tract that may lead to a loss of hydrochloric acid
- Steroid therapy or Cushing's syndrome (hypersecretion of cortisol) that may lead to sodium, hydrogen (H+) ions, and fluid retention
- Ingestion or retention of a base (for example, calcium antacids or $NaHCO_3$)

Symptoms of Metabolic Alkalosis

Symptoms of metabolic alkalosis include

- **Neurological**—Fidgeting and twitching tremors related to hypokalemia or hyperkalemia
- **Respiratory**—Slow, shallow respirations in an attempt to retain CO_2
- **Cardiac**—Atrial tachycardia and depressed T waves related to hypokalemia
- **Gastrointestinal**—Nausea, vomiting, and diarrhea causing loss of hydrochloric acid
- **Lab changes**—pH levels above 7.45, normal or increased CO_2, increased $NaHCO_3$

Caring for the Client with Metabolic Alkalosis

The following items are necessary care items a nurse should know for treating clients with metabolic alkalosis:

- Administering potassium replacements
- Observing for dysrhythmias
- Observing intake and output
- Assessing for neurological changes

CAUTION

A positive Trousseau's sign indicates hypocalcemia and is done by applying a blood pressure cuff to the arm and observing for carpo-pedal spasms. Another assessment tool is the Chvostek's sign, which is done by tapping the facial nerve (C7) and observing for facial twitching. This test also indicates hypocalcemia.

Respiratory Alkalosis

Respiratory alkalosis is related primarily to the excessive blowing off of CO_2 through hyperventilation. Causes of respiratory alkalosis include

- Hypoxia
- Anxiety
- High altitudes

Symptoms of Respiratory Alkalosis

The following list details symptoms of respiratory alkalosis that you will need to know as a nurse and for the exam:

- **Neurological**—Numbness and tingling of hands and feet, tetany, seizures, and fainting
- **Respiratory**—Deep, rapid respirations
- **Psychological**—Anxiety, fear, and hysteria
- **Lab changes**—Increased pH, decreased $PaCO_2$, decreased K+ levels, and normal or decreased CO_2 levels

Care of the Client with Respiratory Alkalosis

The following list includes steps for caring for clients suffering from respiratory alkalosis:

- To correct respiratory alkalosis, the nurse must determine the cause for hyperventilation. Some causes for hyperventilation are stress and high altitudes. Treatments include
  - Stress reduction
  - Sedation
  - Breathing in a paper bag to facilitate retaining CO_2 or using a re-breathing bag
  - Decreasing the tidal volume and rate of ventilator settings

CAUTION

Use the following acronym to help you with respiratory and metabolic questions on the exam:

ROME: Respiratory Opposite, Metabolic Equal

This means, in respiratory disorders the pH is opposite to the CO_2 and HCO_3, and in metabolic disorders the pH is equal to or moves in the same direction as the CO_2 and HCO_3. Here's an explanation:

- Respiratory acidosis—pH down, CO_2 up, HCO_3 up
- Metabolic acidosis—pH down, CO_2 down, HCO_3 down
- Respiratory alkalosis—pH up, CO_2 down, HCO_3 down
- Metabolic alkalosis—pH up, CO_2 up, HCO_3 up

Normal Electrolyte Values

It is important for you to know these normal electrolyte values. You need to be aware of these so that you can associate alterations in them with the acid/base balance. Note that you are likely to encounter questions on the exam that use these values:

- **Sodium (Na+) 135–145 meq/L**—Maintains acid/base balance, maintains extracellular volume, and maintains urine concentration
- **Potassium (K+) 3.5–5.5 meq/L**—Regulates protein synthesis, glycolysis, and glycogen synthesis
- **Calcium (Ca++) 4.5–5.5 meq/L or 8.5–10.5 mg/L**—Helps with the strength and density of bones and teeth, normal clotting, and muscle contractility
- **Chloride (Cl–) 95–105 meq/L**—Assists the formation of hydrochloric acid, maintenance of acid/base balances, and maintaining osmotic pressure

- **Phosphorus (Ph+) 2.5–4.5 mg/dL**—Assists with activation of B complex, cell development, CHO, fat and protein metabolism, and formation and activation of ATP (adenosine triphosphate—creb cycle)
- **Magnesium (Mg++) 1.5–2.5 meq/L**—Helps with muscle contraction, DNA synthesis, and activation of ATP and B complex

Changes Associated with Aging

The following list gives you factors related to fluid and electrolyte balance and acid/base balance with aging clients:

- Presence of chronic health problems such as diabetes mellitus or renal failure
- Poor appetite
- Medications such as diuretics taken by the client
- Skin breakdown
- Osteoporosis
- Lack of muscle mass

Exam Prep Questions

1. The client is admitted to the unit with a potassium level of 2.4 meq/L. The client with a potassium level of 2.4 meq/L would exhibit symptoms of:

- ❍ **A.** Peaked T waves
- ❍ **B.** U waves
- ❍ **C.** Muscle rigidity
- ❍ **D.** Rapid respirations

2. The client is admitted with hypokalemia. An IV of normal saline is infusing at 80 ml/hour with 10 meq of KCl/hour. Prior to beginning the infusion, the nurse should:

- ❍ **A.** Check the sodium level.
- ❍ **B.** Check the magnesium level.
- ❍ **C.** Check the creatinine level.
- ❍ **D.** Check the calcium level.

3. The client is admitted to the labor and delivery unit with preeclampsia. An IV of magnesium sulfate is begun per pump. Which finding would indicate hypermagnesemia?

- ❍ **A.** Urinary output of 60 ml per hour
- ❍ **B.** Respirations of 30 per minute
- ❍ **C.** Absence of the knee-jerk reflex
- ❍ **D.** Blood pressure of 150/80

4. The client presents to the unit with complaints of shortness of breath. A tentative diagnosis of respiratory acidosis related to pneumonia is made. Which finding would support this diagnosis?

- ❍ **A.** pH of 7.45, CO_2 of 45, HCO_3 of 26
- ❍ **B.** pH of 7.35, CO_2 of 46, HCO_3 of 27
- ❍ **C.** pH of 7.34, CO_2 of 30, HCO_3 of 22
- ❍ **D.** pH of 7.44, CO_2 of 32, HCO_3 of 25

5. The client with Cushing's disease will most likely exhibit signs of:

- ❍ **A.** Hypokalemia
- ❍ **B.** Hypernatremia
- ❍ **C.** Hypocalcaemia
- ❍ **D.** Hypermagnesemia

6. The nurse is responsible for teaching the client regarding dietary choices to provide needed magnesium. Which food is a good source of magnesium?

- ❍ **A.** Apple
- ❍ **B.** Spinach
- ❍ **C.** Liver
- ❍ **D.** Squash

7. The client with hyperparathyroidism will exhibit signs of:

- ❍ **A.** Hypokalemia
- ❍ **B.** Hyponatremia
- ❍ **C.** Hypercalcemia
- ❍ **D.** Hyperphosphatemia

8. A client with metabolic acidosis associated with diabetes mellitus is admitted to the unit. A blood glucose of 250 mg/dl is present. Which symptom will most likely accompany ketoacidosis?

- ❍ **A.** Oliguria
- ❍ **B.** Polydipsia
- ❍ **C.** Perspiration
- ❍ **D.** Tremors

9. An elderly client is admitted to the unit with a temperature of 100.2°, urinary specific gravity of 1.032, and a dry tongue. The nurse should anticipate an order for:

- ❍ **A.** An antibiotic
- ❍ **B.** An analgesic
- ❍ **C.** A diuretic
- ❍ **D.** An IV of normal saline

10. Which diet selection contains the most potassium and should be removed from the tray of the client with renal failure?

- ❍ **A.** Peach
- ❍ **B.** Baked potato
- ❍ **C.** Marshmallows
- ❍ **D.** Bread

Answer Rationales

1. Answer B is correct. The normal potassium level is 3.5–5.5 meq/dl. Answer A is incorrect because it indicates an elevated potassium level. Answer C is incorrect because the muscles will be flaccid with hypokalemia. Answer D is incorrect because the respirations will be shallow not rapid.

2. Answer C is correct. The client receiving potassium needs to be evaluated for renal function because regulation of potassium is primarily done within the kidneys. It is not necessary to check the sodium, magnesium, or calcium level prior to beginning potassium, so answers A, B, and D are incorrect.

3. Answer C is correct. The signs of toxicity to magnesium are oliguria (less than 30 ml/hour urinary output), respirations less than 12 per minute, and absence of the deep tendon reflexes. In answer A the urinary output is within normal limits. If it falls below 30, you should further evaluate for toxicity. In answer B if the respirations fall below 12, the infusion should be discontinued and oxygen support maintained. The blood pressure is within normal limits in answer D.

4. Answer B is correct. The client with respiratory acidosis will have a pH that is decreased and CO_2 excretion will be inhibited due to the respiratory problems. The HCO_3 will also be increased because the kidneys are the compensating organ. Answer A is alkalosis, answer C is metabolic acidosis, and answer D is compensated alkalosis.

5. Answer B is correct. The client with Cushing's has hyperadrenal function. These clients retain sodium and water. They do not typically lose potassium or calcium or retain magnesium.

6. Answer B is correct. Dark green vegetables and legumes contain large amounts of magnesium. The other food choices do not provide significant sources of magnesium.

7. Answer C is correct. The client with hyperparathyoidism will have elevated calcium levels. Calcium is pulled from the bone into the serum. These clients frequently have renal calculi and osteoporosis. They do not have hypokalemia, hyponatremia, or hyperphosphatemia. They will have hypercalcemia and hypophosphatemia.

8. Answer B is correct. A blood glucose level of 250 mg/dl is elevated. Symptoms of hyperglycemia are polyuria, polydipsia, and polyphagia. The client will also have a decreased sensorium and tachypnea. Answers A, C, and D are all symptoms of hypoglycemia (testing technique: odd man out).

9. Answer D is correct. The client is hypovolemic and hyponatremic. The slight elevation in the temperature might be related to the dehydration. The normal specific gravity is 1.010–1.020; therefore, this finding shows urinary concentration. There is not enough data to support a need for an antibiotic, as in answer A, an analgesic as in B, or a diuretic as in C.

10. Answer B is correct. The skin of the potato contains large amounts of potassium, and potassium should be limited in the client with renal failure. A peach contains some potassium, but not as much as the baked potato, so answer A is incorrect. The marshmallows and bread contain minimal amounts of potassium, so answers C and D are incorrect.

Suggested Reading and Resources

- Hogan, Mary Ann, Wane, Daryle. *Fluid, and Electrolytes, and Acid-Base Balance*. Upper Saddle River: Pearson, 2003 Lippincott Review Series.
- Paradiso, Catherine. *Lippincott's Review Series, Fluid and Electrolytes and Acid Base Balance*. Philadelphia, PA: Lippincott Company, 1998.
- Rinehart, Sloan, Hurd, *Exam Cram NCLEX-RN*. Indianapolis, IN: Que Publishing, 2005.