Lab Values: Interpreting Chemistry and Hematology for Adult Patients

2 Contact Hours

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Acknowledgments

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Purpose and Objectives

The purpose of this continuing education module is to provide nurses with the knowledge and skills to recognize changes in common chemistry and complete blood count lab values. Additionally, after completing this module, you will be able to discuss reasons why these common lab values may be either elevated or decreased.

After successful completion of this course, you will be able to:

- Identify normal chemistry values for the adult patient
- Define the normal range of laboratory values for components of a complete blood count for the adult patient
- Explain at least two causes and complications of abnormal chemistry values and complete blood count
- Identify at least one treatment associated with abnormal findings

Introduction

Lab values for this course are taken from the Rush Medical Laboratory (Rush University Medical Center, 2015). Remember that there is some variation in ranges based on the laboratory, so be aware of the normal ranges for your facility.

Using laboratory values can be a key piece of assessment to determine what is occurring within the body of a patient. There are numerous laboratory tests that can be done. The most common tests include chemistry panels, hematology (such as the complete blood count), and blood gases. This course will take a closer look at these components.

Introduction to Electrolytes

Electrolytes

The human body is constantly trying to keep a balance of homeostasis with fluid and electrolytes. Electrolytes are chemical compounds that break down into ions, carrying a positive or negative charge. When these are not in balance, pathological changes occur in the human body (LeFever, Paulanka, & Polek, 2010).

Sodium (Na+)

Sodium (Na+) is the major component of extracellular fluid (ECF). The normal values are 137-147 mmol/L

Na+ takes part in the regulation of acid-base balance, tissue osmolality and enzyme activity. Na+ is also essential for the retention of body water by maintaining osmotic pressure (LeFever, Paulanka, & Polek, 2010).

Potassium (K+)

Potassium (K+) is the major component of intracellular fluid (ICF). The normal value range is 3.4-5.3 mmol/L.

K+ participates in enzyme activity, regulation of tissue osmolality and glycogen use. K+ is also essential for cardiac function and central nervous system function by regulating muscle and nerve excitability (LeFever, Paulanka, & Polek, 2010).

Chloride (Cl-)
Chloride (Cl-) is another component of ECF, with normal values between 99-108 mmol/L.

Cl- participates in tissue and cell osmolality, and passively follows sodium and water. Cl- is necessary for K+ retention, transport of carbon dioxide (CO_2), and formation of hydrochloric acid (HCL) in the gastrointestinal tract. Cl- is usually provided in the form of NaCl or KCl (LeFever, Paulanka, & Polek, 2010).

Magnesium (Mg2+)
Magnesium (Mg^{2+}) is found in the bone (50%), the ICF (45%), and the ECF (5%). The normal range is 1.6-2.7 mg/dL.

Mg^{2+} affects enzyme activity, cardiac and neuromuscular function. Deficits with Mg^{2+} are usually seen with deficits in Ca^{2+} and/or K^+ (LeFever, Paulanka, & Polek, 2010).

Calcium (Ca2+)
Calcium (Ca^{2+}) is another component of the ECF, but the majority is found in the bone. The normal values are 8.7-10.7 mg/dL.

Ca^{2+} is essential in blood coagulation, endocrine functions, and neuromuscular function such as muscular contraction and nerve excitability.

Ca^{2+} serum values may vary, depending on total serum protein, as a relationship exists between the two. Abnormal total serum Ca^{2+} levels should be verified with an ionized Ca^{2+} level, as this measurement is independent of serum protein levels. Parathyroid and thyroid hormones as well as vitamin D also influence Ca^{2+} values (LeFever, Paulanka, & Polek, 2010).

Phosphorus (P+)
Phosphorus (P+) is found in the bone and the ICF. The normal range of values is 2.5-4.6 mg/dL.

P+ plays a role in neuromuscular function, formation of bones and teeth, body metabolism of nutrients, and forming and storing of energy such as ATP. A relationship exists between P+ and Ca^{2+}. Therefore, if one value is abnormal, the other should be evaluated as well (LeFever, Paulanka, & Polek, 2010).

Review of Electrolytes

Electrolyte	Value Range	Functions
Sodium (Na+)	137-147 mmol/L	Acid-base balance, osmolality and water retention, enzyme activity
Potassium (K+)	3.4-5.3 mmol/L	Cardiac function, CNS function, enzyme activity, glycogen use
Chloride (Cl-)	99-108 mmol/L	Tissue osmolality, K+ retention, CO2 transport, formation of HCL in GI tract
Magnesium (Mg2+)	1.6-2.7 mg/dL	Enzyme activity, cardiac function, neuromuscular function
Calcium (Ca2+)	8.7-10.7 mg/dL	Blood coagulation, endocrine function, neuromuscular function
Phosphorus (P+)	2.5-4.6 mg/dL	Neuromuscular function, bone and teeth formation, formation and storage of ATP

Test Yourself

Which electrolyte is the major component of ICF and affects cardiac and neuromuscular function?

A. Sodium
B. Potassium
C. Magnesium

The correct answer is B.

Electrolyte Imbalances: Hypernatremia

Hypernatremia and hyperchloremia are related. Causes include:

- Dehydration
- Decreased water intake
- Over-administration of Na+ supplementation
- Diuresis
- Any process that causes a loss of free fluid results in increased Na+ concentration (such as vomiting, diarrhea and insensible water loss through excessive perspiration)
- Impaired renal function
- Cushing's syndrome
- Congestive heart failure

- Metabolic acidosis

Hypernatremia: Clinical Picture

Signs and symptoms of hypernatremia include:

- Anorexia, nausea, vomiting
- Dry tongue and mucous membranes
- Tachycardia
- Hypertension
- Behavior that is restless, agitated
- Altered level of consciousness
- Febrile
- Hyperreflexia
- Tremors or muscle twitching
- Decreased skin turgor
- Concentrated urine

Treatment of hypernatremia is focused on the underlying cause(s) (LeFever, Paulanka, & Polek, 2010).

Electrolyte Imbalances: Hyponatremia

Causes of hyponatremia include:

- Overhydration
- Water retention (water retention causes a dilution of serum Na+, but the total body Na is within normal limits. This can be seen with renal failure, hepatic failure, congestive heart failure, etc.)
- Diuretics
- Low sodium intake
- Prolonged use of D5W (this dilutes the ECF, causing water intoxication)
- Impaired renal function (such as salt-wasting renal disease)
- Syndrome of inappropriate antidiuretic hormone (SIADH)
- Addison’s disease
- Burns
- Fever
- Metabolic alkalosis

Hyponatremia: Clinical Picture

Signs and symptoms of hyponatremia include:

- Diarrhea, nausea, vomiting
- Tachycardia
- Hypotension
- Headaches, lethargy, confusion
- Muscle weakness
- Pallor
- Dry skin and mucous membranes
- Dilute urine

Treatment of hyponatremia is based on the cause(s). Na+ needs to be replaced slowly (LeFever, Paulanka, & Polek, 2010).

Did You Know?

Electrolyte imbalances can occur from a person's diet. In the United States, most people consume too much sodium, and not enough potassium. This is a result of an increased consumption of processed foods, and decreased consumption of natural foods, such as fruits and vegetables (Yang, Liu, Kuklina, Flanders, Hong,et al., 2011).

Electrolyte Imbalances: Hyperkalemia

Potassium levels can be falsely elevated with hemolyzed blood samples. Causes of hyperkalemia include:

- Over-administration of potassium supplements
- Metabolic acidosis
- Renal failure
- Potassium-sparing diuretics
- ACE inhibitors, beta-blockers (both affect potassium balance)
- Trauma/bruising/bleeding (cell breakdown causes potassium loss)
- Addison's disease

Hemolyzed blood samples can cause inaccurate laboratory blood values, including a falsely elevated potassium, also known as pseudohyperkalemia. Hemolysis causes red blood cells to rupture and release potassium into the ECF. Some techniques that cause hemolysis:

- **Application of a tourniquet too tightly (in some cases, just the use of a tourniquet can cause hemolysis)**
- **Clenching of the fist during phlebotomy**
- **Using a small gauge needle (<21g)**

- **Use of a butterfly extension set**
- **Rapid withdrawal of blood during phlebotomy**

Hyperkalemia: Clinical Picture

Clinical signs and symptoms of hyperkalemia include:

- ECG changes: tachycardia, widened QRS, peaked T waves, lengthening of PR interval, P wave difficult to identify, ventricular fibrillation
- Decreased urine output
- Lethargy
- Decreased muscle tone, muscle cramps

Treatment is of the underlying cause(s). If the cause is acidosis, then it must be corrected. Diuretics may be used if renal problem.

In addition, the following are treatments for hyperkalemia:

- Kayexalate: This is a cation-exchange resin, Na+ based (An ion-exchange resin that has the ability to exchange positive ions in the stationary phase with positive ions in solution).
- Calcium administration: Used to decrease the antagonistic effect of potassium excess on the myocardium.
- Insulin/glucose drip: Insulin enhances cellular uptake of K+, forcing it back into cells (LeFever, Paulanka, & Polek, 2010).

Electrolyte Imbalances: Hypokalemia

Causes of hypokalemia include:

- Malnutrition, anorexia
- Decreased K+ intake
- Alcoholism
- K+ losses through vomiting, diarrhea, or gastric suctioning
- Diuretics
- Acute renal failure
- Steroids
- Stress
- Insulin
- Epinephrine, bronchodilators
- Metabolic alkalosis
- Cushing’s syndrome

Hypokalemia: Clinical Picture

Clinical signs and symptoms of hypokalemia include:

- ECG changes: Dysrhythmias, shortened ST segment, flattened or inverted T-waves, appearance of “U” wave
- Intestinal ileus, gastric dilation
- Anorexia, vomiting, diarrhea
- Polyuria
- Malaise, drowsiness, altered level of consciousness
- Muscle weakness

Treatment of hypokalemia includes underlying cause needs to be determined and treated. Any acid-base imbalance needs to be corrected.

- Use K+-sparing diuretics
- K+ supplementation (slowly)
- Identify and correct any other electrolyte imbalances (LeFever, Paulanka, & Polek, 2010)

Test Yourself

Mr. B is a 53 year male, admitted after a motor vehicle accident with a fractured femur and acute renal failure. He has multiple bruises to his face, ribs, right should and arm, and right leg. He has become lethargic, and has decreased urine output. His cardiac monitor begins showing tachycardia, widened QRS, and lengthening PR interval. Which electrolyte imbalance do you suspect?

A. Hypernatremia
B. Hyperkalemia
C. Hypokalemia

The correct answer is B.

His electrolytes are as follows:
Sodium 141 mmol/L
Potassium 6.9 mmol/L
Magnesium 9.5 mg/dL
Calcium 2.3mg/dL.

Based on these findings, what would you anticipate the physician will order?

A. Kayexalate
B. Increasing the sodium concentration in his IV
C. Adding potassium to his IV

The correct answer is A.

Electrolyte Imbalances: Hypermagnesia

Causes of hypermagnesia include:

- Over-administration of magnesium products (including antacids)
- Renal insufficiency
- Renal failure
- Addison’s disease
- Severe dehydration
- Ketoacidosis

Hypermagnesia: Clinical Picture

Signs and symptoms of hypermagnesia include:

- Drowsiness, weakness
- Lethargy
- Loss of deep tendon reflexes
- Paralysis
- Hypotension
- Third degree heart block
- ECG changes: widened QRS complex, prolonged QT interval
- Flushing
- Respiratory depression

Treatment includes treating underlying causes. Use of IV Na^+ or Ca^{2+} can decrease the serum magnesium level. IV calcium is an antagonist to magnesium, which can decrease the symptoms of hypermagnesia. If renal failure is the cause, dialysis may be necessary (LeFever, Paulanka, & Polek, 2010).

Electrolyte Imbalances: Hypomagnesia

Causes of hypomagnesia include:

- Malnutrition or inadequate Mg^{2+} intake
- Malabsorption
- Alcoholism
- Increased Ca^{2+} intake
- Chronic diarrhea
- Diuretics
- Ketoacidosis
- Acute renal failure

- Acute myocardial failure
- Hypokalemia or hypocalcemia
- Metabolic acidosis
- Aminoglycosides, digoxin

Hypomagnesia: Clinical Picture

Clinical signs and symptoms of hypomagnesia include:

- Hyperirritability
- Tremors
- Spasticity
- Hypertension
- Cardiac dysrhythmias: premature ventricular contractions, ventricular tachycardia or fibrillation
- ECG changes: flat or inverted T waves, depressed ST

Treatment includes underlying causes and magnesium replacement therapy (LeFever, Paulanka, & Polek, 2010).

Electrolyte Imbalances: Hypercalcemia

Causes of hypercalcemia include:

- Over-administration of calcium supplements
- Renal impairment
- Thiazide diuretics
- Bone fractures or prolonged immobility
- Malignancy
- Hyperparathyroidism
- Lithium
- Hypophosphatemia

Hypercalcemia: Clinical Picture

Clinical manifestations of hypercalcemia include:

- ECG changes: Diminished ST segment, shortened QT interval, third degree heart block
- Pathologic fractures
- Decreased muscle tone
- Depression
- Flank pain and/or kidney stones

Treatment is aimed at the underlying causes. Normal saline, loop diuretics, calcitonin, and corticosteroids are also used (LeFever, Paulanka, & Polek, 2010).

Electrolyte Imbalances: Hypocalcemia

Causes of hypocalcemia include:

- Dietary deficiencies of calcium, protein, and/or vitamin D
- Chronic diarrhea
- Low albumin
- Renal failure
- Hypoparathyroid
- Hyperphosphatemia
- Hypermagnesia or hypomagnesia
- Alkalosis

More Information:

Calcium Relationships

- Magnesium influences the utilization of potassium, calcium and protein in the body.
- Phophorus and calcium have a negative relationship- if one is elevated, the other is decreased.
- Vitamin D is needed for calcium to be absorbed
- The parathyroid hormone influences the homeostasis of calcium
- About 55% of calcium is bound to protein. The remainder is free calcium, which is physiologically active

Hypocalcemia: Clinical Picture

Clinical signs and symptoms of hypocalcemia include:

- Abnormal clotting
- Tetany, muscle twitches or tremors
- Muscle cramps
- Numbness and tingling
- Irritability, anxiety
- ECG changes: Prolonged QT interval, lengthened ST segment
- Fractures with continued hypocalcemia

Treatment is aimed at the underlying cause: If hypoparathyroid or vitamin D deficits, these needs treatment. Ca^{2+} supplements are used for replacement therapy (LeFever, Paulanka, & Polek, 2010).

Electrolyte Imbalances: Hyperphosphatemia

Causes of hyperphosphatemia include:

- Over-administration of phosphorus supplements
- Hypoparathyroidism
- Renal insufficiency
- Chemotherapy
- Metabolic acidosis
- Respiratory acidosis
- Laxative over-use

Hyperphosphatemia: Clinical Picture

Signs and symptoms of hyperphosphatemia include:

- Hyperreflexia
- Tetany
- Muscle weakness
- Tachycardia
- Nausea and diarrhea
- Abdominal cramps

Treatment may incorporate administration of insulin and glucose, which can lower the serum phosphorus level by shifting phosphorus from the ECF into the cells (LeFever, Paulanka, & Polek, 2010).

Electrolyte Imbalances: Hypophosphatemia

Hypophosphatemia may be caused by:

- Malnutrition, anorexia
- Alcoholism
- Total parenteral nutrition (TPN)
- Vomiting, diarrhea
- Malabsorption
- Hyperparathyroidism
- Ketoacidosis
- Burns
- Metabolic alkalosis
- Respiratory alkalosis
- Diuretics
- Antacids containing aluminum

Hypophosphatemia: Clinical Picture

Clinical signs and symptoms include:

- Muscle weakness
- Tremors
- Bone pain
- Hyporeflexia
- Seizures
- Tissue hypoxia
- Risk of bleeding and infection
- Weak pulse
- Hyperventilation
- Anorexia, dysphagia

Treatment includes replacement of phosphorus through sodium phosphate or potassium phosphate (LeFever, Paulanka, & Polek, 2010).

Test Yourself

Mrs. G. is a 66 year female, admitted with pneumonia. She has a history of hypertension, treated with hydrochlorothiazide, and a recent fall resulting in a wrist fracture. She is started on albuterol and levofloxacin for her pneumonia. She complains of sudden pain in her chest and her flank, and her shortness of breath has increased. An ECG is done, and shows a third degree heart block. Which electrolyte imbalance do you suspect?

A. Hypercalcemia
B. Hypermagnesia
C. Hyperphosphatemia

The correct answer is A.

Her electrolytes are as follows:
Sodium 141 mmol/L
Potassium 3.9 mmol/L
Magnesium 9.5 mg/dL
Calcium 12.1 mg/dL

Based on these findings, what would you anticipate the physician will order?

A. Dextrose infusion
B. Potassium phosphate
C. Change her thiazide diuretic to a loop diuretic

The correct answer is C.

Other Chemistry Tests

In addition to electrolytes, there are other laboratory tests that are included in a complete metabolic panel. This combination of analytes can assist in providing additional information about renal and hepatic function.

Components that will be examined include glucose, serum albumin, amylase, serum creatinine, blood urea nitrogen (BUN), uric acid, alkaline phosphatase, protein, and bilirubin. There are further analytes used in testing which will not be covered at this time.

Glucose

Glucose is a monosaccharide, or a simple sugar, which is a product of cellulose, starch and glycogen. Free glucose occurs in the blood and is the primary source of energy for use in tissues of the body. The normal range is 60-200 mg/dL (non-fasting). Excess glucose is stored as glycogen in the liver or muscle tissue (Warrell, Firth, & Cox, 2010).

Hyperglycemia

Hyperglycemia occurs with a blood glucose greater than 200 mg/dL non-fasting, or a fasting blood glucose >100 mg/dL. Causes of hyperglycemia include:

- Diabetes mellitus
- Hyperosmolar nonketotic syndrome (HNKS)
- Cushing's syndrome
- Increased epinephrine levels from extreme stress (illness, trauma, surgery)
- Excess growth hormone secretion
- Over-administration of glucose
- Pregnancy (gestational diabetes)
- Medications- particularly steroids

Hyperglycemia: Clinical Picture

Signs and symptoms of hyperglycemia may be subtle. These can include:

- Polydipsia- increased thirst
- Dehydration- dry mucous membranes, decreased skin turgor
- Poluria
- Irritability, headaches, confusion
- Decreased level of consciousness
- Changes in vision

Treatment includes increased fluids and insulin administration (Warrell, Firth, & Cox, 2010). Blood glucose levels should be monitored per facility policy.

Hypoglycemia

Hypoglycemia occurs with blood glucose less than 60 mg/dL non-fasting. Causes of hypoglycemia include:

- Imbalance between energy consumption and use- can occur with malnutrition, inadequate nutritional intake and exercise
- Over-administration of insulin
- Liver disease such as hepatitis, cirrhosis, liver cancer
- Over-production of insulin, such as insulin-secreting tumors
- Medications, including beta-blockers, sulfonylureas, and oral hypoglycemic agents
- Infections

Hypoglycemia: Clinical Picture

Signs and symptoms of hypoglycemia may also be subtle. These can include:

- Altered level of consciousness
- Confusion
- Tremors, jitteriness
- Hunger
- Pallor
- Diaphoresis

Treatment includes providing glucose and carbohydrates. Depending on the patient’s status and facility protocol, this may be intravenous or orally (Warrell, Firth, & Cox, 2010). Blood glucose levels should be monitored per facility policy.

Serum Albumin

Albumin is a large protein found in the blood plasma that maintains the osmotic pressure between the blood vessels and tissue. It is also used to determine liver function, kidney function, and nutrition (Warrell, Firth, & Cox, 2010). The normal range for serum albumin is 3.5-4.8 g/dL.

Hypoalbuminemia

Hypoalbuminemia occurs with a serum albumin <3.5 g/dL. Causes may include:

- Poor nutrition
- Liver disease
- Impaired renal function
- Burns
- Lymphatic disease or cancer

- Congestive heart failure
- Inflammatory process

Hyperalbuminemia and Hyperalbuminemia: Clinical Picture

Hyperalbuminemia occurs with a serum albumin >4.8 g/dL. Causes may include:

- Dehydration
- Liver disease
- Impaired renal function

Clinical signs and symptoms of hypoalbuminemia and hyperalbuminemia are related to the disease process involved. Treatment is also focused on the underlying cause(s) (Warrell, Firth, & Cox, 2010).

Test Yourself

Your patient is confused, difficult to arouse, is pale and has diaphoresis. What would you suspect your patient has?

A. Hyperglycemia
B. Hyperalbuminemia
C. Hypoglycemia

The correct answer is C.

Amylase

Amylase is a digestive enzyme that is mainly produced in the parotid glands and pancreas, and is useful in evaluating pancreatic function. The normal range for amylase is 23-85 unit/L.

High and Low Amylase

Increases in serum amylase may be caused by:

- Pancreatitis
- Appendicitis
- Obstructions of biliary tract, pancreatic duct, or gastrointestinal system
- Renal disease
- Ketoacidosis
- Medications, particularly acetaminophen, steroids, antibacterials, narcotics, and aminosalicyclic acids

Decreases in serum amylase may be caused by:

- Liver disease
- Pancreatic insufficiency

Clinical signs and symptoms of abnormal amylase levels are related to the disease process involved. Treatment is also focused on the underlying cause(s) (Warrell, Firth, & Cox, 2010).

Serum Creatinine

Creatinine is the end product of creatine metabolism, which circulates to the kidneys to be excreted. It is used for determining renal clearance and muscle damage. The range for serum creatinine is 0-1.2 mg/dL.

High and Low Creatinine

Increases in serum creatinine may be caused by:

- Muscle damage
- Acromegaly
- Excessive exercise
- Dietary intake of creatine

Decreases in serum creatinine may be caused by:

- Muscle wasting
- Kidney disease
- Leukemia
- Paralysis
- Shock
- Vegetarian diet

Clinical signs and symptoms of abnormal creatinine levels are related to the disease process involved. Treatment is also focused on the underlying cause(s) (Warrell, Firth, & Cox, 2010).

Blood Urea Nitrogen

Blood urea nitrogen (BUN) levels indicate the balance between urea production and excretion. Urea is an end product of protein metabolism, and is a compound of nitrogen from ammonia. Urea distributes into both ECF and ICF, and is excreted by the kidneys. The normal range for BUN levels is 5-20 mg/dL. BUN is usually ordered with creatinine for comparison.

High and Low BUN

Increases in BUN may be caused by:

- Renal failure
- Renal impairment
- Congestive heart failure
- Hypovolemia
- Diabetes
- Ketoacidosis
- Nephrotoxicity
- Shock

Decreases in BUN may be caused by:

- Inadequate protein intake
- Malabsorption
- Pregnancy
- Liver disease

Clinical signs and symptoms of abnormal BUN levels are related to the disease process involved. Treatment is also focused on the underlying cause(s) (Warrell, Firth, & Cox, 2010).

BUN and Creatinine
Creatinine and blood urea nitrogen (BUN) are often ordered together for comparison. The BUN/creatinine ratio is also a useful indicator of disease. The ratio should be between 10:1 and 20:1.

Creatinine is the standard substance for determining renal clearance because a constant quantity is usually produced within the body. The creatinine clearance test measures both a blood and urine specimen sample to determine the rate at which the kidneys are clearing creatinine from the blood. The creatinine clearance reflects the glomerular filtration rate (GFR).

Alkaline Phosphatase

Alkaline phosphatase (ALP) is an enzyme mainly found in the liver, the biliary tract, bones, intestines, and placenta. ALP functions at the highest in alkaline conditions, and is used to evaluate for liver or bone disease. The range for ALP is 30-125 unit/L.

High and Low ALP

Increases in ALP may be caused by:

- Liver disease
- Bone disease
- Cancer
- Pregnancy
- Congestive heart failure
- Pneumonia
- Pulmonary embolism
- Ulcerative colitis

Decreases in ALP may be caused by:

- Anemia
- Vitamin or mineral deficiencies
- Celiac disease
- Autoimmune disorders

Clinical signs and symptoms of abnormal ALP levels are related to the disease process involved. Treatment is also focused on the underlying cause(s) (Warrell, Firth, & Cox, 2010).

Protein

Protein assists in metabolic processes, immune responses, and maintenance of water homeostasis. Protein consists of amino acids, and includes albumin and globulins. The value range for protein is 6-8.2 g/dL.

High and Low Total Protein

Increases in protein levels may be caused by:

- Inflammatory processes
- Dehydration
- Myeloma
- Liver diseases

Decreases in protein levels may be caused by:

- Hemodilution

- Burns
- Malabsorption
- Liver disease
- Renal disease
- Cancer
- Pregnancy
- Starvation

Clinical signs and symptoms of abnormal total protein levels are related to the disease process involved. Treatment is also focused on the underlying cause(s) (Warrell, Firth, & Cox, 2010).

Bilirubin

Bilirubin is a by-product of the breakdown of red blood cells. It is principally produced in the liver, spleen, and bone marrow. Total bilirubin includes unconjugated (indirect), conjugated (direct), and albumin-bound bilirubin. The normal range for total bilirubin is 0.6-1.3 mg/dL.

Hyperbilirubinemia

Hyperbilirubinemia occurs with a total bilirubin >1.3 mg/dL, and causes jaundice with the sclera and skin. Continued bilirubin deposits can accumulate in the brain, causing brain damage or kernicterus.

Increases in bilirubin levels may be caused by:

- Liver diseases
- Trauma
- Biliary obstruction
- Alcoholism
- Starvation
- Hypothyroidism

Treatment may include increasing fluids to assist in bilirubin excretion, and is also focused on the underlying cause(s) (Warrell, Firth, & Cox, 2010).

Test Yourself

Which of the following chemistries assists in evaluating pancreatic function?

A. Glucose
B. Bilirubin
C. Amylase

The correct answer is C.

Review of Analytes

Chemistry Analyte	Value Range	Functions
Glucose (non-fasting)	60-200 mg/dL	Energy production
Serum albumin	3.5-4.8 g/dL	Maintain osmotic pressure; monitor for liver function, renal function, nutrition
Amylase	23-85 unit/L	Digestive enzyme; monitor for pancreatic function
Serum Creatinine	0-1.2 mg/dL	Determining renal function and muscle damage
Blood Urea Nitrogen (BUN)	5-20 mg/dL	By-product of protein metabolism; determines renal function
Alkaline Phosphatase	30-125 unit/L	Enzyme; determines liver and bone disease
Protein	6-8.2 g/dL	Metabolic processes, water homeostasis, immunity
Bilirubin	0.6-1.3 mg/dL	By-product of hemoglobin in red blood cells; determines liver function

Chemistry Panel: Case Study #1

A 22-year-old male patient is brought in via ambulance after being found unresponsive at home. He is difficult to arouse and unable to answer questions. He appears thin, and has poor skin turgor. BP is 100/60, HR 100, RR 16, T 99.2F. The EMS unit started an IV with normal saline, and was unable to obtain a blood glucose reading. The first attempt at arterial blood gas is unsuccessful. The chemistry results return as follows:

- Sodium (Na+) 150 mmol/L
- Potassium (K+) 5.1 mmol/L
- Chloride (Cl-) 88 mmol/L
- Magnesium (Mg2+) 2.6 mg/dL
- Calcium (Ca2+) 9.2 mg/dL
- Phosphorus (P+) 4.2 mg/dL
- Glucose 987 mg/dL

- Creatinine 1.7 mg/dL

Case Study #1

Based on symptoms and lab results, what do you anticipate is occurring with your patient?

A. Sepsis
B. Liver impairment
C. Diabetic ketoacidosis

The correct answer is C.

Chemistry Panel: Case Study #2

You have a 45-year-old female patient, complaining of steady right upper quadrant pain. BP is 138/98, HR 102, RR 14, T 98.9F. She has been experiencing nausea and vomiting x 24 hours. She has poor skin turgor, and you note yellowed sclera. Her abdomen is non-distended but very painful to touch. She rates her pain as a 10. CBC is pending. Chemistry panel results include:

- Sodium (Na+) 147 mmol/L
- Potassium (K+) 2.9 mmol/L
- Chloride (Cl-) 100 mmol/L
- Magnesium (Mg2+) 1.4 mg/dL
- Calcium (Ca2+) 9.2 mg/dL
- Phosphorus (P+) 2.3 mg/dL
- Glucose 188 mg/dL
- Serum albumin 3.0 g/dL
- Amylase 185 unit/L
- Serum Creatinine 0.5 mg/dL
- BUN 15 mg/dL
- Alkaline Phos. 155 unit/L
- Protein 8.6 g/dL
- Bilirubin 3.5 mg/dL

Case Study #2

Based on the patient’s symptoms and lab values, you may suspect any of the following, except:

A. Pancreatitis
B. Renal calculi
C. Biliary obstruction

The correct answer is B.

Complete Blood Count

The complete blood count (CBC) is a commonly ordered laboratory test. Tests included in a CBC include:

- Red blood cell count (RBC)
- Hematocrit (Hct)
- Hemoglobin (Hb or Hgb)
- Red blood cell components, such as mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC)
- White blood count (WBC)
- A differential white blood cell count (diff)
- Platelets

Ranges for normal laboratory values vary among age groups, genders, and laboratories. The laboratory references given in this course are averages; refer to the normal ranges provided by your facility's laboratory.

CBC Overview

Ranges for normal laboratory values vary among age groups, genders, and laboratories. The laboratory references given in this course are averages; refer to the normal ranges provided by your facility's laboratory.

A typical adult circulates about 5 L of blood, which is comprised of 3 L plasma and 2 L of blood cells. White blood cells (leukocytes), red blood cells (erythrocytes), and platelets (thrombocytes) are all created in the bone marrow.

CBC results can be affected by the time of day, hydration, medications, and other blood values.

Red Blood Cells

The primary purpose of RBCs, or erythrocytes, is to carry oxygen from the lungs to body tissues and to transfer carbon dioxide from the tissues to the lungs. Oxygen transfer occurs via the hemoglobin contained in the RBCs, which combines with oxygen and carbon dioxide.

Normal red blood cells values are:

- Adults: (males): 4.6-6.0 million/uL
- (Females): 4.2-5.0 million/uL
- Pregnancy: slightly lower than normal adult values

The average range of values for RBC is 4-5.9 million/uL.

Polycythemia

An increase in the number of red blood cells is known as polycythemia. Causes for polycythemia include:

- High altitudes
- Strenuous physical activity
- Medications, such as gentamicin and methyldopa
- Smoking
- Hydration
- Polycythemia vera
- COPD
- Chronic hypoxia

Polycythemia: Clinical Picture

Symptoms of polycythemia may include:

- Weakness
- Headache
- Fatigue
- Lightheadedness
- Shortness of breath
- Visual disturbances
- Pruritus
- Pain in the chest or leg muscles
- Ruddy complexion
- Confusion
- Tinnitus

Treatment is focused on the underlying cause. Phlebotomy to remove blood or use of medications to decrease red blood cell production may also be used (Van Leeuwen, Poelhuis-Leth, & Bladh, 2013).

Anemia

A decrease in RBCs is known as anemia. Causes of anemia can include:

- Hemorrhage
- Destruction of red blood cells
- Iron deficiency
- Chronic disease processes
- Malnutrition
- Pernicious or sickle cell anemia
- Thalassemia
- Chemotherapy or radiation
- Medications, such as anti-infectives

Anemia: Clinical Picture

Symptoms of anemia may include:

- Fatigue
- Low energy
- Weakness
- Shortness of breath
- Dizziness
- Palpitations
- Pallor
- Chest pain
- Tachycardia
- Hypotension
- Fainting

Treatment is focused on the underlying cause, and dependent on severity. Iron and B12 supplementation is used. The patient may also require blood transfusions (Van Leeuwen, Poelhuis-Leth, & Bladh, 2013).

Hematocrit

The hematocrit (Hct) determines the percentage of red blood cells in the plasma. It is calculated when a blood sample is spun down, and the red blood cells sink to the bottom of the sample.

- Normal hematocrit values are:
- Adults: (males): 40- 54%
- (Females): 37 – 46%
- Pregnancy: decreased hematocrit, especially in the last trimester as plasma volume increases

The average range of values for hematocrit is 37-54%.

Critical values include:

- A hematocrit <15% can cause cardiac failure
- A hematocrit >60% can cause spontaneous blood clotting

Effects on Hematocrit

An increase or decrease in plasma volume affects the hematocrit. Some conditions that affect plasma volume and hematocrit include:

- Burns
- Overhydration or dehydration
- Hemorrhage
- Transfusions

(Van Leeuwen, Poelhuis-Leth, & Bladh, 2013)

Hemoglobin

Hemoglobin (Hgb) is a molecule comprised of an iron-containing pigment (heme) and a protein (globulin). The ability of blood to carry oxygen is directly proportional to its hemoglobin concentration. The number of RBCs may not accurately reveal the blood's oxygen content because some cells may contain more hemoglobin than others.

- Normal hemoglobin values are:
- Adult: (males): 13.5 - 17 g/dl
- (Females): 12 - 15 g/dl
- Pregnancy: 11 - 12 g/dl

The average range of values for hemoglobin is 12-17.5 g/dL.

Critical values include:

- A hemoglobin < 5 g/dl can cause heart failure
- A hemoglobin > 20 g/dl can cause hemoconcentration and clotting

Effects on Hemoglobin

Hemoglobin can be affected by any conditions that affect the RBC count. Conditions that cause polycythemia and anemia also impact the hemoglobin levels. Levels are also affected by disorders that cause abnormal hemoglobin.

MCV, MCH, and MCHC

Mean corpuscular volume (MCV) is the measurement of the average size of individual red blood cells, calculated by dividing the hematocrit by the total RBCs.

Mean corpuscular hemoglobin (MCH) is the measurement of the mass of the hemoglobin in an RBC, calculated by dividing the hemoglobin by the total RBCs.

Mean corpuscular hemoglobin concentration (MCHC) measures how much of each cell is taken up by hemoglobin. The calculation is the hemoglobin divided by the hematocrit and multiplied by 100.

The MCV, MCH, and MCHC can assist in identification and diagnoses of disease processes.

Test Yourself

The ability of blood to carry oxygen is directly proportional to the concentration of which component?

A. Hematocrit
B. Hemoglobin
C. Mean corpuscular volume (MCV)

The correct answer is B.

White Blood Cells

White blood cells (WBC), or leukocytes, are classified into granulocytes (which include neutrophils, eosinophils, and basophils) and agranulocytes (which include lymphocytes and monocytes). WBC are released from the bone marrow and destroyed in the lymphatic system after 14-21 days. Leukocytes fight infection through phagocytosis, where the cells surround and destroy foreign organisms. White blood cells also supply antibodies as part of the body's immune response.

The average range of values for WBC is 4-10 thousand/uL.

WBC critical lab values include:

- A WBC <500 places the patient at risk for a fatal infection.
- A WBC >30,000 indicates massive infection or serious disease (e.g. leukemia)

WBC Differential

The differential consists of the percentage of each of the five types of white blood cells. Normal values for differential are:

- Bands or stabs: 3 - 5 %
- Neutrophils (or segs): 50 - 70% relative value (2500-7000 absolute value)
- Eosinophils: 1 - 3% relative value (100-300 absolute value)
- Basophils: 0.4% - 1% relative value (40-100 absolute value)
- Lymphocytes: 25 - 35% relative value (1700-3500 absolute value)
- Monocytes: 4 - 6% relative value (200-600 absolute value)

Leukocytosis

Leukocytosis occurs with a WBC above 10,000. Some causes of leukocytosis include:

- Trauma
- Inflammation
- Acute infection
- Dehydration
- Hemoconcentration
- Cancer, such as leukemia
- Medications, such as corticosteroids

Treatment is focused on the underlying cause, and dependent on severity (Van Leeuwen, Poelhuis-Leth, & Bladh, 2013).

Leukocytosis: Clinical Picture

Signs and symptoms of leukocytosis may be subtle or related to the disease process occurring. Symptoms may include:

- Fatigue
- Hepatomegaly
- Splenomegaly
- Bleeding
- Bruising or petechiae

Leukopenia

Leukopenia occurs when the WBC falls below 4,000. Some causes of leukopenia include:

- Bone marrow disorders
- Viral infections
- Severe bacterial infections
- Cancer
- Medications, include chemotherapy, antibiotics, anticonvulsants, cardiac medications

Leukopenia: Clinical Picture

Signs and symptoms of leukopenia may be subtle or related to the disease process occurring. Symptoms may include:

- Headache
- Fatigue
- Fever

- Bleeding

Treatment is focused on the underlying cause, and dependent on severity. Steroids, vitamins, and cytokines can be used (Van Leeuwen, Poelhuis-Leth, & Bladh, 2013).

More Information:

Patients with severe leukopenia or neutropenia should be protected from anything that places them at risk for infection. Facilities may have a neutropenic or leukopenic precautions or protocol for these patients. Considerations include:

- **Complete isolation**
- **No injections**
- **No rectal temperatures or enema**

Platelets

Platelets are fragments of cells that are formed in the bone marrow, and are vital to blood clotting. Platelets live for approximately nine to 12 days in the bloodstream.

The average range of values for platelets is 150,000 and 399,000/mm^3.

Thrombocytosis

Thrombocytosis is an increase in platelets >399,000. Some causes of thrombocytosis include:

- Injury
- Inflammatory process
- Bone marrow disorder
- Cancer
- Kidney disease
- Acute blood loss
- Infection

Thrombocytosis: Clinical Picture

Signs and symptoms of thrombocytosis include:

- Dizziness
- Headache
- Chest pain
- Weakness
- Neuropathy
- Vision changes
- Fainting

Treatment is focused on the underlying cause, and dependent on severity (Van Leeuwen, Poelhuis-

Leth, & Bladh, 2013).

Thrombocytopenia

Thrombocytopenia occurs when the platelet count is <150,000, placing the patient at a high risk for bleeding due to injury or disease. A platelet count <20,000 can cause spontaneous bleeding that may result in patient death. Some causes of thrombocytopenia include:

- Impaired platelet production
- Disseminated intravascular coagulation (DIC), which uses up platelets rapidly
- Immune disorders
- Suppression of bone marrow through chemotherapy, radiation, or other therapy
- Cancer

Thrombocytopenia: Clinical Picture

Signs and symptoms of thrombocytopenia include:

- Easy bruising or bleeding
- Hematuria
- Black, tar-like stools or frank bleeding with bowel movements
- Hematemesis
- Syncope
- Visual disturbances

Treatment is focused on the underlying cause, and dependent on severity. Platelet transfusions may be used with severe thrombocytopenia (Van Leeuwen, Poelhuis-Leth, & Bladh, 2013).

Review of CBC

Component	Value Range	Functions
Red Blood Cells (RBC)	4-5.9 mil/uL	Carry oxygen to tissues
Hematocrit	37-54%	Percentage of RBCs in plasma
Hemoglobin	12-17.5 g/dL	Responsible for oxygen carrying capacity of RBCs
White Blood Cells	4-10 th/uL	Fight infection; supply antibodies
Platelets	150-399 x $10^3/mm^3$	Participate in blood clotting

CBC Values: Case Study #1

You have a 62-year-old male patient, complaining of fatigue, dizziness, and bleeding from his gums. On assessment, you notice multiple bruises on upper and lower extremities, back and trunk. BP is 138/98, HR 88, RR 12, T 100.9F. His CBC results are as follows:

- Red Blood Cells (RBC) 4.5 million/uL
- Hematocrit 40%
- Hemoglobin 3.2 g/dL
- White Blood Cells 2.9 thousand/uL
- Platelets 99 x $10^3/mm^3$

Based on his symptoms and lab results, what action would you anticipate with this patient?

A. Prepare to transfuse packed red blood cells
B. Place the patient in isolation with neutropenic precautions
C. Anticipate the need to administer oxygen

The correct answer is B.

CBC Values: Case Study #2

Your patient is a 24-year-old female, with a history of drug abuse. She is complaining of shortness of breath, dizziness, chest pain and palpitations. She appears pale and malnourished. BP 90/56, HR 106, RR 18, T 98.2F, O2 sat 89%. Her CBC results are as follows:

- Red Blood Cells (RBC) 3.3 million/uL
- Hematocrit 23%
- Hemoglobin 9 g/dL
- White Blood Cells 4.9 thousand/uL
- Platelets 199 x $10^3/mm^3$

Based on her symptoms and lab results, what action would you anticipate with this patient?

A. Prepare to transfuse packed red blood cells
B. Place the patient in isolation with neutropenic precautions
C. Anticipate administration of corticosteroids

The correct answer is A.

Conclusion

Common blood tests for patients include electrolyte panels and complete blood counts. It is important for nurses as members of the interdisciplinary care team to be able to recognize abnormal lab values, and anticipate plans of care and treatment for their patients.

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