Medical Education Systems, Inc.

OVERVIEW OF LABORATORY INTERPRETATION

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202 OVERVIEW OF LABORATORY DATA

LEARNING OBJECTIVES

Upon completion of this section, given an open-book, multiple-choice exam, you will be able to apply the information learned to correctly answer a minimum of 80% of the test items. Successful completion of this exam will require you to have mastered the following learning objectives:

1. Give the normal values for each of the following laboratory tests:

   a. Serum sodium
   b. Serum potassium
   c. Serum chloride
   d. CO_2 content
   e. Serum calcium
   f. Serum phosphorus
   g. LDH
   h. SGOT
   i. Serum glucose
   j. Bilirubin
   k. BUN
   l. Creatinine
   m. RBC
   n. Hematocrit
   o. Hemoglobin
   p. WBC
   q. Differential

2. Indicate the importance of each of the following electrolytes in maintaining various body functions:

   a. Serum sodium
   b. Serum potassium
   c. Serum chloride
   d. CO_2 content
   e. Serum calcium
   f. Serum phosphorus

3. Identify clinical conditions that can produce an increase or decrease in each of the following electrolytes:

   a. Serum sodium
   b. Serum potassium
   c. Serum chloride
   d. CO_2 content
   e. Serum calcium
   f. Serum phosphorus

4. Indicate the primary role of glucose in the body.

5. Name the primary condition responsible for an elevated serum glucose.

6. Recognize clinical conditions that can produce an increase or decrease in each of the following enzymes:

   a. LDH
   b. SGOT

7. Name the physiologic mechanism responsible for bilirubin production.

8. Indicate clinical conditions that can produce an increased bilirubin.

9. Describe the normal physiology associated with the production of the following substances:

   a. Urea
   b. Creatinine

10. Identify the significance of an elevation in the following substances:

    a. BUN
    b. Creatinine

11. Recognize the clinical conditions that can cause the following laboratory manifestations:

    a. Polycythemia
    b. Anemia
    c. Increased hematocrit
    d. Decreased hematocrit
    e. Decreased hemoglobin

12. Indicate the two measurements that are normally given for the WBCs.

13. Identify the role of each of the following types of WBCs and indicate the significance of an increase in each:

    a. Neutrophils
    b. Eosinophils
    c. Basophils

    d. Lymphocytes

e. Monocytes

14. Recognize the significance of each of the following microbiology tests:

    a. Gram stain
    b. Culture
    c. Sensitivity
    d. Acid-fast

15. Classify common bacteria according to their gram stain.

SUPPLEMENTAL READING

For your own benefit we recommend reviewing the supplemental reading. It is not required, however it will inhance your knowledge of the subject.

Wilkins, **Clinical Assessment in Respiratory Care**, C.V. Mosby Company.

INTRODUCTION

The management of the respiratory patient involves both evaluation and treatment. Evaluation of the patient is necessary to determine the most beneficial medical treatment. Follow-up evaluation is performed to determine the effectiveness of the treatment and any detrimental effects.

Proper administration of respiratory modalities necessitates an understanding of arterial blood gases, ventilatory parameters, chest x-rays, auscultation, clinical assessment, and cardiovascular assessment. Because the respiratory system functions in concert with the rest of the body, the respiratory care practitioner must also be familiar with laboratory data that is either directly or indirectly related to the management of respiratory patients.

The focus of this section will be on the basic physiology, normal values, and pathological causes for abnormalities occurring in laboratory data. The significance of each type of laboratory data will be discussed.

ELECTROLYTES

Electrolytes are important in acid-base balance, fluid balance, electrical activity of the nerves, skeletal muscles and heart, and in blood clotting. A single electrolyte value provides little information about the metabolic status of the patient. Only by comparing the various electrolyte values can an evaluation be made.

Sodium

Sodium is the major cation in extracellular fluid. Sodium plays an important role in acid-base balance, fluid balance, and muscle function. The normal value is 136-142 mEq/L.

Changes in the sodium level are seldom seen because its concentration is related to the extracellular osmolality. Sodium is the primary factor in maintaining the osmolality of the extracellular fluid since sodium and water tend to move together.

Hypernatremia

An increased serum sodium is the result of either a large increase in sodium without proportional increase in water, or a loss of water without a proportional loss of sodium. An increase in the serum sodium becomes apparent only when there is not a sufficient amount of water in the body (mainly in the intercellular space) to balance the increased sodium level, resulting in a total body water deficit.

A very common cause of hypernatremia is excessive administration of sodium-containing intravenous solutions to the unconscious patient unable to respond with a thirst mechanism. Other causes of hypernatremia include dehydration, steroid administration, and renal dysfunction.

Hyponatremia

Hyponatremia is more common than hypernatremia. Like hypernatremia, hyponatremia may not accurately reflect the total level of sodium in the body because sodium is usually lost with water. For example, the most common cause of hyponatremia is overhydration. Therefore, serum hyponatremia may be associated with a decreased, normal, or increased quantity of total body sodium.

Hyponatremia associated with a sodium loss

Most commonly, hyponatremia is associated with decreased total body sodium. Addison's disease is an example of a condition producing hyponatremia with a decrease of total body sodium.

The primary dysfunction in Addision's disease is decreased sodium reabsorption by the kidney. The patient with Addison's disease will also be hyperkalemic and mildly dehydrated. Chronic glomerulonephritis also results in decreased reabsorption of sodium by the kidney. In glomerulonephritis, the renal tests will be abnormal and the BUN will be elevated. Other causes of hyponatremia that are associated with decreased total body sodium include:

1. Loss of gastrointestinal fluids by vomiting, diarrhea, or nasogastric drainage
2. Loss of sodium through the skin by burns
3. Loss of sodium through the kidneys due to use of diuretics
4. Metabolic loss of sodium through starvation

Dilutional Hyponatremia

This condition is associated with a decreased serum sodium with a normal or even an excess concentration of total body sodium. Excessive IV administration is the most common cause of dilutional hyponatremia. In this situation, the excess water dilutes the serum resulting in a reduced serum sodium concentration. However, the actual total body sodium remains normal. Other conditions that produce a dilutional hyponatremia include:

1. Chronic diuretic use with sodium restriction
2. Oliguria
3. Diabetic acidosis without adequate sodium replacement
4. Congestive heart failure

Potassium

Potassium is the major cation of intracellular fluid. Potassium affects acid-base balance, cellular osmotic pressure, and cellular membrane electrical potential. The small amount of potassium in the serum affects neuromuscular and myocardial function. Small changes in the serum potassium can have dramatic effects on the heart, resulting in serious cardiac arrhythmias. The normal value for serum potassium is 3.8-5.0 mEq/L.

Hyperkalemia

Hyperkalemia occurs most frequently in renal failure because of inadequate urine output. The intake of too much potassium can also cause hyperkalemia. This is particularly true in IV administration of supplemental potassium. The danger of producing hyperkalemia by oral medications containing potassium is minimal if the urine output is adequate.

Because cells contain large quantities of potassium, anything that destroys cells (i.e., burns and tissue injury) will result in a reduction in the intracellular level of potassium. The intracellular potassium often spills over into the extravascular fluid creating a temporary hyperkalemia. However, the hyperkalemia is eventually followed by a hypokalemia.

Finally, hyperkalemia is associated with metabolic acidosis. Two mechanisms are responsible for the increased serum potassium. First, the kidneys excrete H^+ and retain potassium. Second, there is an exchange of potassium and H^+ at the cellular level. This is a buffering mechanism wherein some of the excess H^+ moves into the cells in exchange for potassium. Conversely, a primary hyperkalemia will result in an acidotic state because of the same cellular and renal mechanisms.

Hypokalemia

Hypokalemia usually represents a depletion of total body potassium. Hypokalemia is rarely caused by inadequate intake of potassium because the required daily amount of potassium is quite low.

The primary cause of hypokalemia is an excessive loss of potassium. Loss of fluid from the GI tract reduces the total body potassium and results in hypokalemia. Chronic diuretic administration (with most diuretics) combined with an inadequate potassium chloride supplementation can result in an absolute loss in total body potassium and hypokalemia.

An alkalotic state also results in a decreased serum potassium. This is due to an increase retention of H^+ while potassium is excreted. Also, at the cellular level, H^+ shifts, out of the cells while potassium moves into the cells, thus producing a hypokalemic state. Conversely, a primary hypokalemia will result in an alkalotic state because of the same cellular and renal mechanisms.

Chloride

Chloride is present in fairly large quantities in the serum and has an important influence on acid-base balance and osmotic pressure. The normal value is 95-103 mEq/L.

Hyperchloremia

Hyperchloremia is most often associated with renal tubular acidosis, decreased CO_2 content, and hypokalemia.

Hypochloremia

Hypochloremia is most often associated with hypokalemia and alkalosis, which is called hypokalemic-chloremic alkalosis.

CO_2 Content

The CO_2 content provides a means of evaluating the acid-base status via the serum electrolytes. The test measures the total carbonic acid and bicarbonate in the plasma. The normal value is 24-30 mM/L.

Elevated CO_2 Content

If no chronic obstructive lung disease is present, an elevated CO_2 content indicates a serum alkalosis. This serum alkalosis will be accompanied by an intracellular acidosis. The serum will also show a hypokalemia and hypochloremia.

Low CO_2 Content

A low CO_2 content is associated with metabolic acidosis if a normal pH is present. If the arterial pH is alkalotic, a low CO_2 content indicates an acute respiratory alkalosis due to hyperventilation.

Calcium

Over 98% of the calcium in the body resides in the bones and teeth. The amount of calcium in the extracellular fluid is very small. Of the calcium that does occur in the plasma, approximately 50% is in the ionized form. This ionized calcium is important in blood coagulation and electrical activity of the heart, muscles, and nerves.

Serum calcium is regulated by the parathyroid gland. Parathyroid hormone raises the plasma level of ionized calcium by 1) causing the bones to release calcium into the extracellular space, 2) increasing the rate of absorption of calcium in the intestine, and 3) increasing the retention of calcium by the kidney. Calcium absorption in the intestine is controlled by vitamin D which increases the ability of the intestine to absorb calcium. Calcium and phosphorus, both cations, are related elements which work in combination to maintain an electrical balance. A loss in extracellular calcium results in an increase in phosphorus.

Hypercalcemia

The causes of hypercalcemia include the following conditions:

1. Hyperparathyroidism

2. Milk-alkali syndrome (increased calcium ingestion)

Hypocalcemia

The causes of hypocalcemia include the following conditions:

1. Hypoparathyroidism
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2. Vitamin D deficiency

3. Pregnancy

4. Excessive intake of diuretics

5. Respiratory alkalosis and hyperventilation

Phosphorus

Of the total phosphorus in the body, 85% is combined with calcium in the bones. Phosphorus and calcium will occur in a 1:1 ratio with adequate quantities of vitamin D. Parathyroid hormone causes an increased rate of absorption of phosphorus by the gut, but causes phosphate to be lost in the urine while calcium is retained. The normal serum phosphate is 3.0-4.5 mEq/L.

Hyperphosphatemia

Hyperphosphatemia is associated with the following conditions:

1. Chronic glomerular disease with elevated BUN and creatinine

2. Hypothyroidism (with hypocalcemia)

3. Increased calcium ingestion

Hypophosphatemia

Hypophosphatemia is associated with the following conditions:

1. Hyperparathyroidism (in associated with hypercalcemia)
2. Adult osteomalacia (vitamin D deficiency)
3. Childhood rickets (vitamin D deficiency)
4. Chronic use of phosphate binding antacids
5. Rapid correction of hyperglycemia and diabetic ketoacidosis

MISCELLANEOUS LAB VALUES

Blood Glucose

Most carbohydrates taken into the body are converted to form glucose or fructose. The fructose is eventually converted into glucose by the liver. Glucose is the primary substance required in cellular metabolism. The normal serum glucose is 70-110 mg/100 ml.

Hyperglycemia

Hyperglycemia is usually associated with diabetes. A serum glucose greater than 500 mg/100 ml indicates uncontrolled diabetes. This is confirmed by a significantly reduced CO_2 content, which is a compensation for the presence of ketoacidosis.

Hypoglycemia

A fasting hypoglycemia is quite rare and is usually associated with pancreatic islet cell tumor or pituitary hypofunction.

Bilirubin

Bilirubin is a normal waste by-product of red blood cell decomposition that results from the destruction of red blood cells by the reticuloendothelial system. As the red blood cells reach the end of their life span, they become fragile and their cell membranes rupture. The released hemoglobin is phagocytized by the reticuloendothelial cells throughout the body. The end result of the phagocytosis is bilirubin.

Excess bilirubin in the blood diffuses into the tissues giving the skin a yellowish color, called jaundice. Jaundice may be the result of 1) excessive production of bilirubin, 2) decreased ability of the liver to convert and excrete bilirubin, and 3) obstruction of the excretory ducts in the liver from which the bilirubin is excreted.

The normal value for bilirubin in adults is 0.1-1.2 mg/dl. In newborn infants the normal value is 1-12 mg/dl. An elevated bilirubin combined with a low hemoglobin is indicative of massive hemolysis. The bilirubin may be elevated up to 20 mg/dl in newborns with Rh incompatibility. However, about 50% of all newborns will have some degree of jaundice because their red blood cells have a short life span and the liver is not yet effective in converting the bilirubin for excretion. This is referred to as physiological jaundice and disappears within a few days. Liver dysfunction can also cause an increase in the bilirubin because of an inability to convert the bilirubin for excretion.

Blood Urea Nitrogen (BUN)

Urea is one of the primary vehicles for excreting excess nitrogen resulting from protein metabolism. The urea is formed as a result of the breakdown of amino acids in the liver. After urea is formed in the liver, it goes into the blood stream and is eventually excreted in the urine. Because the urea is excreted by the kidneys, the BUN is a good indicator of renal function. The normal value for the BUN is 8-18 mg/dl.

Elevated BUN

Any condition that impairs renal function will result in an elevated BUN. Acute or chronic renal failure is the most common cause of an elevated BUN. Renal failure may be the result of kidney damage or disease, or may simply be the result of reduced perfusion. Thus, an elevated BUN can be seen in the patient in shock or in congestive heart failure. Dehydration may also produce an elevated BUN due to the reduced urine output.

Azotemia is a term indicating an increase of nitrogenous waste products, particularly urea, in the plasma due to renal failure. This condition often requires dialysis to remove the excess urea and other toxic substances not excreted by the kidneys. However, not all patients with elevated BUN levels require dialysis since it is possible for the BUN level to be reduced by improving the function of the kidney, that is, by treating the underlying disease (i.e., congestive heart failure, dehydration).

Decreased BUN

A decreased BUN is usually a result of overhydration. A marked reduction in protein metabolism also tends to result in reduced levels of BUN.

Serum Creatinine

Creatinine is a waste product of creatine metabolism. Creatine is a high energy substance that is present in the skeletal muscles. Like urea, creatinine is excreted by the kidneys. As a result, the creatinine level is another means of evaluating kidney function. The normal value for creatinine is 0.6-1.2 mg/dl.

Elevated Serum Creatinine

Creatinine is elevated in all diseases of the kidney in which more than 50% of the nephrons have been destroyed. In fact, the only pathological condition that will cause an increase in the creatinine level is significant damage to the nephrons of the kidneys. Creatinine will not be elevated if there is only moderate renal insufficiency. An elevation in the creatinine is always a sign of severe kidney damage.

ENZYMES

Enzymes are substances that speed up chemical reactions. Enzymes are found in all tissues, and each type of tissue has a particular enzyme associated with it. For example,

serum glutamic oxaloacetic transaminase (SGOT) is found mainly in the heart muscle, skeletal muscle, liver, and kidney. An elevation of a particular enzyme indicates that a particular tissue has been damaged, thus releasing its specific enzymes.

Lactic Dehydrogenase (LDH)

LDH is an enzyme that catalyzes the reversible oxidation of lactic acid to pyruvic acid. LDH is present in nearly all metabolizing cells, with the highest concentrations occurring in the heart, liver, brain, skeletal muscles, and red blood cells. Damage to any of these tissues causes the enzyme to increase in the plasma. LDH levels as high as 1500 can be associated with myocardial infarction or hemolytic disorders. Slight elevation in the LDH (500-700) may indicate any of the following entities:

1. Chronic hepatitis
2. Malignancies of the skeletal muscles, liver, kidney, brain, or heart
3. Destruction of the pulmonary tissue due to pneumonia or emboli
4. CVAs with brain damage

The normal value for serum LDH is 100-225 U/ml.

Serum Glutamic Oxaloacetic Transaminase (SGOT)

SGOT is responsible for the conversion of amino acids into keto acid and the reverse. SGOT is found mainly in the heart muscle, liver, kidney, and red blood cells. The enzyme is released into the plasma and may be detected within 8 hours after tissue injury, usually peaking within 24 to 36 hours. The SGOT level increases proportionately with the amount of tissue damage.

The normal value for SGOT is 8-33 U/ml. An extreme elevation in the SGOT is associated with myocardial infarction, hepatitis, liver necrosis, and skeletal muscle damage. Moderate elevations in the SGOT can be seen in the following conditions:

1. Congestive heart failure
2. Pericarditis
3. Pulmonary infarction
4. Post-traumatic states
5. Generalized infections such as mononucleosis

HEMATOLOGY

In a complete blood count (CBC) the following determinations are made:

1. White blood cell count (WBC)
2. Red blood cell count (RBC)

3. Hematocrit

4. Hemoglobin

5. Differential white cell count (Diff)

Red Blood Cell Count (RBC)

The RBC is a count of the number of blood cells per cubic millimeter of blood. The normal value is 4.6-6.2 million/mm^3 in the adult male and 4.2-5.4 million/mm^3 in the adult female.

Red blood cells are formed in the red bone marrow. As mentioned previously, red blood cells are constantly dying and being replaced. However, red blood cell production is also stimulated by anemia and hypoxia. A hormone secreted by the kidneys, called erythropolietin, stimulates the production of red blood cells when anemia or hypoxia occurs. Tissue hypoxia is the ultimate stimulus for increased red blood cell production.

<u>Polycythemia</u>

Normal physiological increases in the RBC occur in people living at high altitudes. Also, an increased RBC is observed in well trained athletes who generate an increased demand for oxygen during exercise.

There are two pathological conditions in which the RBC can be elevated. The first is called polycythemia vera. Its cause is unknown, but it is known that the cause is not hypoxia. The second condition in which the RBC count can be elevated occurs in COPD.

This increase is due to tissue hypoxia and is referred to as secondary polycythemia. Secondary polycythemia is also seen in children with congenital heart defects.

The increased viscosity of blood in polycythemic patients increases thrombotic phenomena. Additionally, patients with polycythemia exhibit cyanosis at higher oxygen saturations. Thus, these patients may be very cyanotic while being adequately oxygenated.

<u>Anemia</u>

"Anemia" is a broad term describing the condition in which the total amount of hemoglobin in the red cells is reduced. The reduction in the total hemoglobin can be the result of any of the following conditions:

1. Abnormal loss of erythrocytes

2. Abnormal destruction of erythrocytes

3. Lack of needed elements or hormones for erythrocyte production

4. Suppression of bone marrow activity

Generally speaking, anemia can occur as the result of three basic principles: 1) a reduction in the total number of RBCs, 2) a reduction in the hemoglobin in the RBCs, or 3) both of the above working in combination.

Anemia reduces the amount of oxygen available to the tissues. As opposed to patients with polycythemia, anemic patients can be severely hypoxic and not appear cyanotic.

Hematocrit

Hematocrit is the percentage of RBCs in a volume of plasma. The hematocrit is found by centrifuging a tube of blood, which packs the RBCs at the bottom of the tube. The results assume that the plasma volume is normal. For example, a dehydrated patient will show an elevated hematocrit. The normal value for the hematocrit is 45-52% in adult males and 37-48% in adult females.

Increased Hematocrit

Any condition that causes a decrease in the plasma volume will result in an increased hematocrit, even though there has not been an actual increase in the RBCs. If the patient's hydration status is normal, an increased hematocrit indicates a real increase in the RBCs.

Decreased Hematocrit

A decreased hematocrit can be the result of overhydration, or a real decrease in the number of RBCs. The latter is the more common cause.

Hemoglobin

Hemoglobin is the oxygen-carrying portion of a red blood cell and is reported as gm/100 ml of blood. If each RBC has a normal amount of hemoglobin, the hematocrit is approximately three time the hemoglobin level. For example, a hemoglobin of 15 gm/100 ml would indicate a hematocrit of about 45%. The normal value for the hemoglobin is 13.0-18.0 g/100 ml in the adult male and 12-16 g/100 ml in the adult female.

Increased Hemoglobin

The normal RBC contains the optimum amount of hemoglobin. Thus, any increase in the hemoglobin must be evaluated in relation to the number and size of the RBC.

Decreased Hemoglobin

All conditions that result in a decreased RBC will also have a decreased hemoglobin. This being so, the most common cause of a reduced hemoglobin is blood loss.

Total White Blood Count (WBC)

The total WBC is the number of cells per cubic millimeter of blood. The normal value is, 4,500 to 11,000/mm^3. Two measurements of the white blood cells are normally done. The first is the total number of WBCs and the second is the differential WBC count, which gives the percentage of each of the various leukocytes.

The normal percentage for each of the leukocytes are given below:

neutrophils	61%
eosinophils	4%
basophils	1%
lymphocytes	26%
monocytes	5%

Neutrophils

Neutrophils are the body's first line of defense against bacterial infections and severe stress. Neutrophils are important WBCs because they are major phagocytes. An increase in the neutrophils is referred to as neutrophilia.

Eosinophils

An increase in the eosinophils is known as eosinophilia. Eosinophils seem to play a significant role in antigen-antibody reactions. The most common clinical conditions associated with eosinophilia are allergic reactions such as asthma, hayfever, or hypersensitivity to certain drugs. Eosinophils apparently act like antibodies to neutralize foreign antigens that enter the blood.

Basophils

The main function of basophils is the secretion of heparin. The percentage of basophils does not normally change.

Lymphocytes

Lymphocytes are the principal components of the body's immune system. Lymphocytes function primarily as plasma cells to secrete antibodies during infections.
Lymphocytes increase in many viral infections, including mumps and infectious hepatitis. Chronic bacterial infections also cause an increase in the percentage of lymphocytes.

Monocytes

Like the neutrophils, monocytes function as phagocytes. Although they are present in smaller numbers compared to the neutrophils, the monocytes are capable of phagocytizing much larger volumes of microbes and foreign materials. Monocytes seem to function as phagocytes in certain chronic inflammatory diseases including tuberculosis and protozoan and rickettsial infections.

Gram Stain

A gram stain provides a means of obtaining a broad classification of bacterial organisms. A gram stain does not provide enough information to identify the specific organism. However, enough information is provided via the gram stain to help in an initial diagnosis as well as helping to rule out certain suspected organisms. The gram stain classifies bacteria into one of four groups:

1. Gram-positive rods

2. Gram-positive cocci

3. Gram-negative rods

4. Gram-negative cocci

Bacteria can be further classified according to whether the organism's metabolism is aerobic or anaerobic. Table 1 lists some of the common bacteria according to their gram stain and type of metabolism.

Table 1

CLASSIFICATION OF COMMON BACTERIAL ORGANISMS

Aerobic Organisms	Anaerobic Organisms
Gram-positive Cocci	Gram-positive Cocci
Staphylococcus aureus	Anaerobic streptococci
Streptococcus pneumoniae	Gram-positive Rods
Gram-negative Cocci	Clostridium
Neisseria meningitidis	Gram-negative Rods
Neisseria gonorrhea	Bacteroides
Gram-negative Rods	
Escherichia coli	
Proteus	
Klebsiella	
Pseudomonas	

Cultures

Cultures are done if it is necessary to identify the specific organism involved in an infection in order to properly manage the patient. After the bacterium is grown on an agar plate, various analyses are performed to identify the organism. For most commonly-cultured bacteria, the results of a culture can be produced in two to three days. However, some bacteria reproduce very slowly. Mycobacterium tuberculosis is an example of a slow-reproducing organism. The final results of a culture for tuberculosis may take from 3 to 8 weeks.

Sensitivity Tests

Sensitivity tests determine which antibiotic will have the optimum inhibitory effect on the infection bacterium. Most commonly, the bacterium is cultured on an agar plate and then paper disks impregnated with various antibiotics are placed on the culture plate. The laboratory report indicates the degree to which the various antibiotics inhibited the growth of the bacterium. If the growth is inhibited by a certain antibiotic, it is reported as "S" for sensitive. An "R" indicates that the bacterium is resistant to the antibiotic while an "I" indicates that the bacterial growth is partially inhibited.

Acid-Fast Stain

The acid-fast stain is most commonly used in the initial diagnosis determination of the presence of mycobacterium organisms. Since the culture of tuberculosis organisms can take up to 8 weeks, the acid-fast stain provides a faster method for identifying the presence of tuberculosis so that therapy can be initiated.

Refer to Table 2 for a summary of laboratory values.

Table 2

SUMMARY OF LABORATORY VALUES

Electrolytes	Value	
Serum Sodium	136-142 mEq/L	
Serum Potassium	3.8-5.0 mEq/L	
Serum Chloride	95-103 mEq/L	
CO_2 content	24-30 mM/L	
Serum Calcium	4.5-5.3 mEq/L	
Serum Phosphorus	3.0-4.5 mEq/L	
Enzymes	**Value**	
LDH	100-225 units	
SGOT	8-33 U/ml	
Others	**Value**	
Serum Glucose	70-110 mg/100 ml	
Bilirubin	0.1-1.2 mg/dl (adults)	
	1-12 mg/dl (newborns)	
BUN	8-18 mg/dl	
Creatinine	0.6-1.2 mg/dl	
Hematology	**Value**	
RBC	4.6-6.2 million/mm^3 (adult male)	
	4.2-5.4 million/mm^3 (adult female)	
Hematocrit	45-52% (adult male)	
	37-48% (adult female)	
Hemoglobin	13-18 g/100 ml (adult male)	
	12-16 g/100 ml (adult female)	
WBC	4500 to 11,000/mm^3	
Differential	Neutrophils	61%
	Eosinophils	4%
	Basophils	1%
	Lymphocytes	26%
	Monocytes	5%

STUDY OUTLINE

I. Introduction

A. Management of the respiratory patient involves both treatment and evaluation

1. Preliminary evaluation determines the most beneficial treatment

2. Follow-up evaluation checks the effectiveness and detrimental effects

B. Lab work even distantly related to the respiratory system must be understood by the practitioner

II. Electrolytes

A. Important in acid-base balance, fluid balance, electrical activity, and in blood clotting.

1. Is valuable data only in its entirety; a single electrolyte value is of little use

B. Sodium

1. The major cation in extracellular fluid

a. Normal value is 136-142 mEq/L

b. Changes in level are seldom seen because of its relationship with extracellular fluid's osmolality

2. Hypernatremia

a. Caused by either a sodium increase or a water loss

b. Often due to administration of sodium-containing intravenous solutions to unconscious patients

c. Other causes are dehydration, steroids, and renal dysfunction

3. Hyponatremia

a. More common; also either a sodium loss or water gain

b. Most common cause is overhydration

c. Hyponatremia associated with a sodium loss

1) Addison's disease - decreased sodium reabsorption

by the kidney

2) Chronic glomerulonephritis

3) Loss of gastrointestinal fluids

4) Sodium loss through burns, use of diuretics, starvation

d. Dilutional Hyponatremia

1) Excessive IV administration

2) Chronic diuretic use with sodium restriction

3) Oliguria

4) Diabetic acidosis without sodium replacement

5) Congestive heart failure

C. Potassium

1. The major cation of intracellular fluid

a. Normal value is 3.8-5.0 mEq/L

b. Small changes in the serum potassium can have dramatic effects on the heart

2. Hyperkalemia

a. Occurs most frequently in renal failure

b. Also due to intake of too much potassium (IV administration, oral medications)

c. Cell destruction releases potassium into the intercellular fluid

d. Metabolic acidosis

1) Kidneys excrete H^+, retain potassium

2) Cellular exchange of H^+ and potassium

3. Hypokalemia

a. Usually represents depletion of total body potassium

b. Primary cause is an excessive loss of potassium (fluid from the GI tract, excessive diuretic use)

c. Alkalotic state

1) H^+ exit from cells, entrance of potassium

D. Chloride

1. Present in large quantities in serum
   a. Normal value is 95-103 mEq/L
2. Hyperchloremia
   a. Usually associated with renal tubular acidosis, decreased CO_2 content, and hypokalemia
3. Hypochloremia
   a. Most often associated with hypokalemia and hypokalemic-chloremic alkalosis

E. CO_2 content

1. CO_2 content is a way to evaluate acid-base status
   a. The test measures total carbonic acid and bicarbonate in the plasma
   b. Normal value is 24-30 mM/L
2. Elevated CO_2 content
   a. When no COPD is present, elevated CO_2 indicates serum alkalosis
3. Low CO_2 content
   a. If the pH is normal, metabolic acidosis is indicated
   b. If the pH is alkalotic, low CO_2 indicates acute respiratory alkalosis due to hyperventilation

F. Calcium

1. 90% of the body's calcium is stored in the teeth and bones; extracellular calcium is very low
   a. 50% of extracellular calcium is ionized and is important in blood clotting and electrical activity.

   b. Serum calcium is regulated by parathyroid hormone which raises plasma level by :
      1) Causing bones to release calcium
      2) Increasing intestinal absorption of calcium

3) Increasing kidney's calcium retention

c. Serum calcium loss results in phosphorus increase

2. Hypercalcemia

a. Caused by hyperparathyroidism, milk-alkali syndrome

3. Hypocalcemia

a. Caused by hypoparathyroidism, vitamin D deficiency, pregnancy, excessive use of diuretics, respiratory alkalosis, and hyperventilation

G. Phosphorus

1. 85% of the body's phosphorus is combined with calcium in the bones

a. Normal levels are 3.0-4.5 mEq/L

2. Hyperphosphatemia

a. Caused by chronic glomerular disease with elevated BUN and creatinine, hypothyroidism, and increased calcium ingestion

3. Hypophosphatemia

a. Associated with hyperparathyroidism, adult osteomalacia, childhood rickets, chronic use of phosphate binding antacids, and rapid correction of hyperglycemia and diabetic ketoacidosis

III. Miscellaneous Lab Values

A. Blood glucose

1. Most ingested carbohydrates are converted to glucose or fructose (and later glucose, by liver)

a. The normal values are 70-110 mg/100 ml

2. Hyperglycemia

a. Usually associated with diabetes

1) Serum glucose over 500 mg/100 ml indicates uncontrolled diabetes

3. Hypoglycemia

a. Fasting hypoglycemia is rare; usually associated with pancreatic islet cell tumor or pituitary hypofunction

B. Bilirubin

1. Is a normal by-product of RBC decomposition by the reticuloendothelial system

a. The released hemoglobin is phagocytized, and bilirubin results

2. Excess bilirubin diffuses into tissues, causing jaundice

a. Due to excessive production of bilirubin or decreased conversion and excretion by liver, or obstruction of liver's excretory ducts

3. Normal values are 0.1-1.2 mg/dl in adults and 1-12 mg/dl in infants

a. 50% of all newborns have some jaundice, but it should disappear within a few days

C. Blood urea nitrogen (BUN)

1. Urea is the major vehicle for excreting nitrogen by-products of protein metabolism

a. BUN is a good indicator of renal function

b. Normal values are 8-18 mg/dl

2. Elevated BUN

a. Commonly due to acute or chronic renal failure

1) Can only be seen in shock, congestive heart failure or dehydration

b. Azotemia (increased nitrogenous waste in plasma due to renal failure) often requires dialysis

3. Decreased BUN

a. Usually a result of overhydration, sometimes a marked reduction in protein metabolism

D. Serum creatinine

1. Creatinine is a waste product of creatine metabolism; excreted by the kidneys

a. Is a means of evaluating kidney function

b. The normal values are 0.6-1.2 mg/dl

2. Elevated serum creatinine

a. Occurs in all diseases of the kidney in which more than 50% of the nephrons have been destroyed

IV. Enzymes

A. Found in all tissues, they are tissue-specific

1. An elevation of one enzyme indicates that its source tissue has been damaged

B. Lactic dehydrogenase (LDH)

1. Catalyzes the reversible oxidation of lactic acid to pyruvic acid, is present in most metabolizing cells

2. Normal value is 100-225 U/ml

a. Values to 1500 associated with myocardial infarction or hemolytic disorders

b. Values of 500-700 may indicate chronic hepatitis, malignancies of skeletal muscles, liver, kidney, brain or heart, pulmonary tissue destruction due to emboli or pneumonia, or CVAs with brain damage

C. Serum glutamic oxaloacetic transaminase (SGOT)

1. Involved in the reversible conversion of amino acids to keto acid; found mainly in heart, liver, kidney, and red blood cells

a. Is detected in plasma within 8 hours of tissue injury, usually peaking in 24 to 36 hours

2. Normal value is 8-33 U/ml

a. Extreme elevations are associated with myocardial myocardial infarction, hepatitis, liver necrosis, and damage to skeletal muscle

b. Moderate elevations seen in congestive heart failure, pericarditis, pulmonary infarction, post-traumatic states, and generalized infections

V. Hematology

A. In a complete blood count, one measures WBC count, RBC count, hematocrit, hemoglobin, and the differential WBC count

B. RBC Count

1. Counts the number of RBCs per cubic mm of blood

a. Normal values are 4.6-6.2 million/mm^3 (adult male) and 4.2-5.4 million/mm^3 (adult female)

b. RBC production is stimulated by anemia and hypoxia

2. Polycythemia

a. Normal increases in RBC count are seen in high-altitude dwellers and trained athletes

b. Polycythemia vera cause is unknown (but it is not due to hypoxia)

c. COPD can cause RBC count elevation

d. Increased viscosity of blood increases thrombotic phenomena

3. Anemia

a. Defined as a reduction in the total hemoglobin

b. Caused by loss or destruction of RBCs, lack of elements or hormones for RBC production, suppression of bone marrow activity

c. Occurs as the result of loss of RBCs, reduction of hemoglobin, or a combination of both

d. Anemic patients can be severely hypoxic and not appear cyanotic

4. Hematocrit is the percentage of RBC in a volume of plasma (assume that plasma volume is normal)

a. Normal values are 45-52% (adult male) and 37-48%

(adult female)

b. Increased hematocrit may be from a decrease in plasma volume, or an actual increase in RBCs

c. Decreased hematocrit may be from overhydration or an actual decrease in RBCs

5. Hemoglobin is the oxygen-carrying portion of the RBC

a. Normal values are 1/3 the hematocrit level

b. Increased hemoglobin is often the result of blood loss

c. Decreased hemoglobin is often the result of blood loss

C. Total white blood cell count (WBC)

1. The number of cells per cubic millimeter of blood

a. Normal value is 4, 5000-11,000/mm^3

2. The differential WBC count gives the percentage of each type of WBC

a. Neutrophils (61%) are phagocytes, defending the body against bacterial infections and severe stress

b. Eosinophils (4%) are involved in antigen-antibody reactions, neutralizing foreign antigens

c. Basophils (1%) secrete heparin; normally, their number remains constant

d. Lymphocytes (26%) function as plasma cells to secrete antibodies during infections

e. Monocytes (5%) are phagocytes, valuable in certain chronic inflammatory diseases

VI. Microbiology

A. Gram stain

1. Is a useful classification tool, helps to establish an initial diagnosis

a. The 4 resulting classifications may be further separated according to whether they are aerobic or anaerobic

B. Cultures

1. Cultures are grown if it is necessary to identify the specific

organism involved in an infection

a. Some cultures are rapid (2-3 days), others can take weeks to develop

2. Sensitivity tests

a. Cultures are tested with various antibiotics to determine which are the most effective

1) In reporting the results, "S" means sensitive, "R" indicates resistant, and "I" means growth was partially inhibited

3. Acid-fast stain

a. Used to identify mycobacteria, which are too slow-growing to make their culture practical

GLOSSARY

Arrhythmias- an irregularity in the force or rhythm of the heartbeat.

Azotemia- A toxic condition resulting from kidney disease in which there is retention in the bloodstream of waste products normally excreted in the urine. Also called uremia.

Basophils- A tissue that stains readily with basic dyes.

Bilirubin- the orange-yellow pigment in bile, causing jaundice if it builds up in the blood and skin; the levels of bilirubin in the blood are used to diagnose liver disease

Cation- An ion or group of ions having a positive charge and characteristically moving toward the negative electrode in electrolysis.

Cocci- bacteria having a spherical or spheroidal shape

Creatinine- a waste product that is filtered from the blood by the kidneys and expelled in urine

Eosinophils- a granulocytic, bilobed leukocyte somewhat larger than a neutrophil characterized by large numbers of coarse, refractile, cytoplasmic granules that stain with the acid dye, eosin. Eosinophils constitute 1% to 3% of the white blood cells of the body. They increase in number with allergy and some parasitic infections and decrease with steroid administration.

Glomerular- of or pertaining to glomerulus, especially a renal glomerulus.

Glomerulonephritis- inflammation of the filtering structures in the kidneys, hindering removal of waste products from the blood

Hematocrit- The percentage by volume of packed red blood cells in a given sample of blood after centrifugation.

Hypercalcemia- a condition marked by abnormally high levels of calcium in the blood; can lead to disturbance of cell function in the nerves and muscles and, if not treated, can be fatal

Hyperchloremia- an excessive level of chloride in the blood.

Hyperglycemia- a condition characterized by abnormally high levels of glucose in the blood, usually as a result of untreated or improperly controlled diabetes mellitus.

Hyperkalemic- greater than normal amounts of potassium in the blood. This condition is seen frequently in acute renal failure. Early signs are nausea, diarrhea, and muscle weakness. As potassium levels increase, marked cardiac changes are observed in the ECG. Treatment of severe hyperkalemia includes the intravenous administration of sodium bicarbonate, calcium salts, and dextrose. Hemodialysis is used if these measures fail.

Hypernatremia- a greater than normal concentration of sodium in the blood, caused by excessive loss of water and electrolytes resulting from polyuria, diarrhea, excessive sweating, or inadequate water intake. When water loss is caused by kidney dysfunction, urine is profuse and dilute. Care must be taken to restore water balance slowly, because further electrolyte imbalances may occur.

Hypocalcemia- a deficiency of calcium in the serum that may be caused by hypoparathyroidism, vitamin D deficiency, kidney failure, acute pancreatitis, or inadequate plasma magnesium and protein.

Hypochloremia- a decrease in the chloride level in the blood serum, below 95 mEq/L. The condition may occur as a result of prolonged gastric suctioning.

Hypoglycemia- abnormally low levels of glucose in the blood

Hypokalemia- a condition in which an inadequate amount of potassium, the major intracellular cation, is found in the circulating bloodstream. Hypokalemia is characterized by abnormal ECG, weakness, and flaccid paralysis and may be caused by starvation, treatment of diabetic acidosis, adrenal tumor, or diuretic therapy.

Hyponatremia- a less than normal concentration of sodium in the blood, caused by inadequate excretion of water or by excessive water in the circulating bloodstream. In a severe case, the person may develop water intoxication, with confusion and lethargy, leading to muscle excitability, convulsions, and coma. Fluid and electrolyte balance may be restored by intravenous infusion of balanced solution.

Ketoacidosis- the dangerous accumulation of chemicals called ketones in the blood, sometimes occurring as a complication of diabetes mellitus; also called ketosis

Lymphocytes- a white blood cell that is an important part of the body's immune system, helping to destroy invading microorganisms

Monocytes- a large mononuclear leukocyte, 13 to 25 [grk m] m in diameter with an ovoid or kidney shaped nucleus, containing chromatin material with a lacy patter and abundant gray blue cytoplasm filled with fine, reddish and azurophilic granules.

Neutrophils- a ploymorphonuclear, granular leukocyte that stains easily with neutral dyes. The nucleus stains dark blue and contains three to five lobes connected by slender threads of cromatin. The cytoplasm contains fine, inconspicuous granules.

Nutreophils are the circulating white blood cells essential for phagocytosis and proteolysis which bacteria, cellular debris, and solid particles are removed and destroyed.

Oliguria- a diminished capacity to form and pass urine, less than 500 ml in every 24 hours, so that the end products of metabolism cannot be excreted efficiently. It is usually caused by imbalances in bodily fluids and electrolytes, by renal lesions, or by urinary tract obstruction.

Osteomalacia- the loss of minerals and softening of bones because of a lack of vitamin D; called rickets in children

Pericarditis- inflammation of the membranous sac that covers the heart, causing chest pain and fever

Polycythemia- an increased amount of red blood cells in the blood

Reticuloendothelial- Of, relating to, or being the widely diffused bodily system constituting all phagocytic cells except certain white blood cells.

Post Test

Instructions: Select the single most correct response.

1. The normal value for the serum sodium is:

   A. 4-5 mEq/L
   B. 24-30 mEq/L
   C. 95-103 mEq/L
   D. 105-112 mEq/L
   E. 136-142 mEq/L

2. Which of the following conditions can cause hypocalcemia?

   A. Hyperparathyroidism
   B. Vitamin D deficiency
   C. Respiratory acidosis
   D. Oliguria
   E. Milk-alkali syndrome

3. Hyperkalemia is associated with which of the following conditions?

   I. Metabolic acidosis
   II. Addison's disease
   III. Dehydration
   IV. Diarrhea

   A. I only
   B. II only

C. I and III
D. II and III
E. II and IV

4. An SGOT level of 1550 U/ml would be compatible with which of the following?

I. Chronic hepatitis
II. Myocardial infarction
III. CVA
IV. Congestive heart failure

A. II only
B. IV only
C. I and II
D. II and IV
E. I, II, and III

5. Which of the following is most commonly associated with an increased BUN?

A. Anaerobic metabolism
B. Renal failure
C. Congestive heart failure
D. Liver damage
E. Myocardial infarction

6. An increased level of eosinophils is associated with which of the following conditions?

A. Asthma
B. Bacterial infections
C. Decreased heparin production
D. Viral infections
E. Rickettsial infections

7. Hyponatremia is associated with?

   A. Loss of sodium through the skin by burns
   B. Metabolic loss of sodium through starvation
   C. Addison's disease
   D. All of the above
   E. None of the above

8. Serum calcium is regulated by?

   A. The heart
   B. The liver
   C. The kidneys
   D. The parathyroid gland
   E. The RBC

9. Anemia is a result of?

   A. Abnormal loss of erythrocytes
   B. Abnormal destruction of erythrocytes
   C. Lack of needed elements or hormones for erythrocyte production
   D. Suppression of bone marrow activity
   E. All of the above

10. The normal value per cubic millimeter of white blood cells (WBC) is?

   A. 45-110
   B. 450-1100
   C. 4,500-11,000
   D. 45,000-110,000
   E. 450,000-1,100,000

11. CO_2 content in the blood is normally what value?

   A. 31- 40 mM/L
   B. 23- 30 mM/L
   C. 16- 22 mM/L
   D. 41- 56 mM/L

12. A patient receiving I.V. fluids in excess of his ability to excrete these fluids would cause:

   A. Hyperkalemia
   B. Hypokalemia
   C. Reduced BUN
   D. Hypotension
   E. Hypochloremia

13. The normal value for Chloride is:

   A. 23- 30 mEq/L
   B. 44- 56 mEq/L
   C. 95- 103 mEq/L
   D. 200- 232 mEq/L

14. Over 75% of the calcium in the body resides in the bones and teeth

   True
   False

15. Calcium absorption in the intestine is controlled by:

A. Renal Perfusion
B. Cardiac Output
C. Uric Acid
D. Vitamin D

16. Excess bilirubin will cause:

A. Rickets
B. Hypertension
C. Jaundice
D. Hyperphosphatemia

17. Normal Eosinophils % is:

A. 5%
B. 4%
C. 52%
D. 3%

18. White Blood Cell count greater than 11,000/mm usually means:

A. Polycythemia
B. Diabetes
C. Cardiac Infarction
D. Infection

19. Basophils main function is to:

A. Fight infection
B. Decrease antigen-antibodies
C. Secrete antibodies
D. Secrete heparin

20. Which of the following are Anaerobic Organisms

I. Gram-negative Rods
II. Neiseria meningitidis
III. Clostridium
IV. Staphylococcus

A. I only
B. I, III
C. II, III
D. III, IV
E. All of the above

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