Brief Notes on

Laboratory and Diagnostic Tests

PHCL 326

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Laboratory and Diagnostic Tests

Learning Objectives

- Differentiate between invasive and noninvasive tests.
- State the clinical application of common general diagnostic procedures.
- Identify the clinical application of specific laboratory tests.
- Identify the clinical application of specific diagnostic procedures.
- Assess common laboratory and diagnostic test results.

Laboratory tests are helpful tools in evaluating the health status of an individual. Laboratory results may be outside of the "normal range" for many reasons. This deviation from the normal value may be due to several factors such as race, diet, age, sex, menstrual cycle, degree of physical activity, problems with collection and/or handling of the specimen, non-prescription drugs (aspirin, cold medications, vitamins, etc.), prescription drugs and a number of non-illness-related factors. It is not possible to diagnose or treat any disease or problem with this blood test alone. It can, however, help you to learn more about your body and detect potential problems in early stages when treatment or changes in personal habits can be most effective.

The following pages review the laboratory and diagnostic tests commonly encountered in the patient care environment. The tests are presented using an organ system approach (i.e., cardiovascular, endocrine, gastrointestinal, hematologic, immunologic, neurologic, renal, and respiratory).

Laboratory and diagnostic tests are classified as either invasive or noninvasive tests.

**Invasive tests:**

These tests require penetration of the skin or insertion of instruments or devices into a body orifice. The degree of risk with invasive tests varies from relatively minor risks such as the pain, bleeding, and bruising associated with venipuncture to the risk of death associated with more invasive procedures such as coronary angiography.
Examples of invasive tests:
- collection of blood (venipuncture)
- insertion of a central venous catheter
- collection of cerebrospinal fluid.

Noninvasive tests:
In these tests, the skin is not penetrated or instruments are not inserted into body orifices. They pose little risk to the patient.
Examples of noninvasive tests:
- chest radiograph
- analysis of spontaneously voided urine
- stool occult blood analysis.

Factors to consider when interpreting individual test results:
- patient age
- gender
- timing of the test result in relationship to drug administration
- concomitant drug therapy
- concurrent diseases
- organ function (e.g., renal function, liver function, cardiac function)
- test sensitivity (the proportion of true-positive results)
- test specificity (the proportion of true-negative results)
- timing of the test in relation to drug dosing or known circadian rhythms
- genetics (e.g., glucose-6-phosphate deficiency)
- fluid status (e.g., euvolemia, dehydration, fluid overload).

LABORATORY TESTS AND DIAGNOSTIC PROCEDURES

- **Angiography**: تصوير الأوعية الدموية
  a radiographic test used to evaluate blood vessels and the circulation.
  Radiopaque material is injected through a catheter, and images are recorded using standard radiographic techniques.
• **Biopsy**: خَزْعَة
involves the removal and evaluation of tissue.

• **Computed Tomography**: تصوير مقطعي محسب
(CT; CAT scan) uses a computerized x-ray system to produce detailed sectional x-ray images. The system is very sensitive to differences in tissue density and produces detailed, two-dimensional planar images; contrast agents increase attenuation. The spiral or helical CT takes pictures continuously, decreasing the time needed to obtain images.

• **Doppler Echography**: تخطيط دوبلير للصدأ
Doppler echography uses ultrasound technology to measure shifts in frequency from moving images. For example, it is used to evaluate blood flow velocity and turbulence in the heart (Doppler echocardiography) and peripheral circulation.

• **Endoscopy**: تنظير داخلي
used to examine the interior of a hollow viscus (e.g., digestive, respiratory, and urogenital organs and the endocrine system) or canal (e.g., bile ducts, pancreas). The endoscope, a flexible or inflexible tube with a camera and light source, is inserted into a body orifice. Still and/or video images are recorded and tissues obtained for biopsy or other laboratory diagnostic tests.
CARDIOVASCULAR SYSTEM

A variety of noninvasive and invasive laboratory and diagnostic tests are used to evaluate and monitor the cardiovascular system.

LABORATORY TESTS

Cardiac Enzymes.

The pattern and time course of the appearance of enzymes in the blood after cardiac muscle cell damage are used to diagnose myocardial infarction (MI).

Creatine Kinase (CK; creatine phosphokinase)

It is found in skeletal muscle; cardiac muscle; and the brain, bladder, stomach, and colon. Isoenzyme fractions identify the type of tissue damaged. CK-BB (CK1) is found in the brain, bladder, stomach, and colon; CK-MB (CK2) is found in cardiac tissue; and CK-MM (CK3) is found in skeletal muscle. CK-MB is detected in the blood within 3 to 5 hours after a myocardial infarction; levels peak in about 10 to 20 hours and normalize within about 3 days.

<table>
<thead>
<tr>
<th>Creatine kinase</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK-MB</td>
<td></td>
<td>0-7.5 ng/ml</td>
</tr>
<tr>
<td></td>
<td>40-150 U/L</td>
<td>60-400 U/L</td>
</tr>
</tbody>
</table>

Lactic Dehydrogenase (LDH)

It is found in a variety of body tissues. Isoenzyme fractions are used to identify the type of tissue damage.

- LDH₁ and LDH₂: found in the heart, brain, and erythrocytes. LDH₂ normally accounts for the highest percentage of total serum LDH. After a myocardial infarction (MI) the rise in LDH₁ concentration exceeds the rise in LDH₂ concentration (the LDH₁-to-LDH₂ ratio is >1; a “flipped” ratio).
- LDH₃ is found in the brain and kidneys.
- LDH₄ is found in the liver, skeletal muscle, and kidneys.
- LDH₅ is found in the liver, skeletal muscle, and ileum.

LDH increases within about 12 hours after a myocardial infarction, peaks between 24 and 48 hours, and normalizes by about day 10.

<table>
<thead>
<tr>
<th>Lactic dehydrogenase</th>
<th>110-210 U/L</th>
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</thead>
<tbody>
<tr>
<td>Lactic dehydrogenase isoenzymes</td>
<td></td>
</tr>
<tr>
<td>LDH₁</td>
<td>17%-27%</td>
</tr>
<tr>
<td>LDH₂</td>
<td>28%-38%</td>
</tr>
<tr>
<td>LDH₃</td>
<td>18%-28%</td>
</tr>
<tr>
<td>LDH₄</td>
<td>5%-15%</td>
</tr>
<tr>
<td>LDH₅</td>
<td>5%-15%</td>
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</tbody>
</table>
Cholesterol.

Cholesterol is separated into lipoproteins by protein electrophoresis:
- Low-density lipoprotein (LDL) is **strongly** correlated with coronary artery disease.
- High density lipoprotein (HDL) is **inversely** correlated with coronary artery disease.

<table>
<thead>
<tr>
<th>Lipids</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholesterol</td>
<td>&lt;200 mg/dl</td>
</tr>
<tr>
<td>Triglycerides (fasting)</td>
<td>40-150 mg/dl</td>
</tr>
</tbody>
</table>

C-Reactive Protein.

C-reactive protein is a biologic marker of systemic inflammation.
↑C-reactive protein concentration ↑risk of myocardial infarction, ↑stroke, ↑peripheral arterial disease.

<table>
<thead>
<tr>
<th>C-reactive protein</th>
<th>Value</th>
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<tbody>
<tr>
<td></td>
<td>&lt;8 µg/ml</td>
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</tbody>
</table>

Myoglobin.

Myoglobin is a small protein found in cardiac and skeletal muscle. The presence of myoglobin in the urine or plasma is a relatively sensitive indicator of cellular damage.

Triglycerides.

Triglycerides are found in very-low-density lipoproteins (VLDLs) and chylomicrons.

Troponins.

Thery are a complex of proteins (troponin I, C, and T) that mediate the actin and myosin interaction in muscle.
- Troponin I and T are specific to cardiac muscle and are used to identify cardiac muscle injury.
- Troponin I and T concentrations increase within a few hours of cardiac muscle injury and remain elevated for 5 to 7 days.

<table>
<thead>
<tr>
<th>Troponins</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troponin I</td>
<td>&lt;0.35 ng/ml</td>
</tr>
<tr>
<td>Troponin T</td>
<td>&lt;0.2 µg/L</td>
</tr>
</tbody>
</table>
ENDOCRINE SYSTEM

- Endocrine system consists of:
  Pituitary - hypothalamus - adrenal gland - thyroid gland - parathyroid glands - pancreas.

- Assessed by measuring the levels of the hormones produced by the different components of the system

LABORATORY TESTS

- **Adrenal Tests**

  **Adrenal Medulla.**
  The adrenal medulla secretes catecholamines. The 24-hour urinary excretion of epinephrine, norepinephrine, and vanillylmandelic acid (VMA) is used to assess the function of the adrenal medulla.

  **Adrenal Cortex.**
  The adrenal cortex secretes mineralocorticoids, glucocorticoids, and androgens. Tests used to assess the function of the adrenal cortex include plasma and urine aldosterone; plasma renin activity; serum testosterone; serum estradiol; plasma cortisol (morning and evening); plasma adrenocorticotropic hormone (ACTH) (morning); and urinary excretion rates of the 17-hydroxycorticosteroids, 17-ketogenic steroids, and 17-ketosteroids.

- **Pancreatic Tests**

  **Amylase.**
  Amylase is secreted by the pancreas, bowel, parotids, and gynecologic system. Although not specific for pancreatitis, serum amylase is easier to measure than is lipase and is used as a common screening and monitoring parameter for acute pancreatitis. However, in chronic pancreatitis the pancreas may be “burned out” and unable to secrete amylase.

  **c Peptide.**
  C peptide is an inactive peptide chain released from beta cells in equimolar amounts with insulin and found in the serum in about a 5:1 to 15:1 ratio with insulin. C peptide is sometimes used to assess pancreatic function.

  **Glucose.**
  Serum glucose concentrations are used to assess pancreatic function and the response to insulin replacement therapy.

    **Fasting Serum Glucose.**
    The serum sample is obtained after 10 to 14 hours of fasting. The fasting serum glucose is usually obtained before breakfast after an overnight fast.
**Glucose Tolerance Test.**
The glucose tolerance test (GTT) is used to diagnose diabetes mellitus and gestational diabetes. Patients fast for 10 to 16 hours before the test and are then given approximately 75 g of glucose. Serial blood samples are obtained, and the serum glucose concentration is determined. Normally, the serum blood glucose is less than 200 mg/dl at 30, 60, and 90 minutes and less than 140 mg/dl at 2 hours.

**Random Serum Glucose.**
The random serum glucose sample can be obtained at any time without fasting.

**Glycosylated Hemoglobin.**
(hemoglobin A1c, HbA1c, A1C, or Hb1c; sometimes also HbA1c).
Glycosylated hemoglobin is formed when hemoglobin is irreversibly glycosylated after exposure to high glucose levels. Glycosylated hemoglobin assesses long-term control of insulin therapy and differentiates factitious hyperglycemia from diabetes.

**Insulin.**
Fasting serum insulin is sometimes obtained during the assessment of pancreatic function.

**Lipase.**
Lipase is a specific marker for acute pancreatic disease. Increases in serum lipase parallel increases in serum amylase. However, in chronic pancreatitis the pancreas may be “burned out” and unable to secrete lipase.

<table>
<thead>
<tr>
<th>Test</th>
<th>Unit</th>
<th>Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amylase (Serum)</td>
<td></td>
<td>53-123 U/L</td>
</tr>
<tr>
<td>Glucose (fasting) (Plasma)</td>
<td></td>
<td>70-110 mg/dl</td>
</tr>
<tr>
<td>Insulin (fasting) (Serum)</td>
<td></td>
<td>0-29 μU/ml</td>
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</tbody>
</table>

**Thyroid Tests.**
Thyroid function tests are used to establish the level of thyroid function (e.g., hyperthyroid, hypothyroid, euthyroid) and the response to suppressant or replacement therapy. Thyroid function is assessed by evaluating the serum concentrations of the free hormones thyroxine (T4) and triiodothyronine (T3) and by a number of indirect methods.

**Free Thyroxine Index.**
The free thyroxine index (FT4I) is the product of the measured T4 and the triiodothyronine uptake (T3U). It takes into account the absolute hormone level and the binding capacity of thyroid-binding globulin. The FT4I is decreased in hypothyroidism and increased in hyperthyroidism.
Thyroid-Stimulating Hormone (Thyrotropin).
Serum TSH, or thyrotropin, levels are used to differentiate between thyroid hypothyroidism and pituitary hypothyroidism. The TSH level is elevated in thyroidal hypothyroidism and markedly decreased in pituitary hypothyroidism.

Thyroid Uptake of Radioiodine.
Radioactive iodine (\(^{123}\)I or \(^{131}\)I) is administered orally, and the radioactivity over the thyroid gland is counted at various intervals. The normal radioactive iodine uptake (RAIU) is about 10% to 35%.

Thyrotropin-Releasing Hormone.
Thyrotropin-releasing hormone (TRH) stimulates the pituitary to release TSH. Injection of synthetic TRH normally causes an increase in TSH in about 30 minutes.

Triiodothyronine Uptake.
The triiodothyronine uptake (T3U) test is an in vitro test that indirectly estimates the amount of thyroid-binding globulin in the serum.

<table>
<thead>
<tr>
<th>Thyroid</th>
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</thead>
<tbody>
<tr>
<td>Free thyroxine index</td>
<td>4.6-11.2</td>
</tr>
<tr>
<td>Thyroid-stimulating hormone (Serum)</td>
<td>0.5-5 μU/ml</td>
</tr>
<tr>
<td>Total triiodothyronine (T3) (Serum)</td>
<td>75-195 ng/dl</td>
</tr>
<tr>
<td>Total thyroxine (T4) (Serum)</td>
<td>4-12 μg/dl</td>
</tr>
</tbody>
</table>
GASTROINTESTINAL SYSTEM

- **Biliary System.**
  Bilirubin is useful in the diagnosis and monitoring of liver disease and hemolytic anemia and in the assessment of the severity of jaundice. A patient is generally visibly jaundiced if the bilirubin level is greater than 2 mg/dl.

  **Alkaline Phosphatase.**
  Alkaline phosphatase is elevated in biliary cirrhosis, cirrhosis, and intrahepatic bile duct disease.

<table>
<thead>
<tr>
<th>Alkaline phosphatase</th>
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</thead>
<tbody>
<tr>
<td>Female (Serum)</td>
<td>30-100 U/L</td>
</tr>
<tr>
<td>Male (Serum)</td>
<td>45-115 U/L</td>
</tr>
</tbody>
</table>

- **Direct Bilirubin.**
  Direct bilirubin is water-soluble conjugated posthepatic bilirubin. It is increased with biliary disease (e.g., extrahepatic bile duct obstruction, physical impairment of bile flow, impaired bile transport) and some liver disease (e.g., hepatitis, cirrhosis, hepatic neoplasm).

- **Delta Bilirubin.**
  Delta bilirubin is albumin-bound conjugated bilirubin. A calculated value \[\text{delta bilirubin} = \text{total bilirubin} - (\text{unconjugated bilirubin} + \text{conjugated bilirubin})\], delta bilirubin is metabolically inactive and cleared slowly from the body. Delta bilirubin is increased with biliary obstruction and some liver disease.

- **Indirect Bilirubin.**
  Indirect bilirubin is unconjugated bilirubin. It is increased with hemolytic anemia (rapid, severe hemolysis) and some liver disease.

- **Total Bilirubin.**
  Total bilirubin is the sum of all three forms of bilirubin (direct bilirubin, indirect bilirubin, and delta bilirubin). Total bilirubin is increased with hepatic and hemolytic disease.

<table>
<thead>
<tr>
<th>Bilirubin</th>
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</thead>
<tbody>
<tr>
<td>Direct (Serum)</td>
<td>Up to 0.4 mg/dl</td>
</tr>
<tr>
<td>Total (Serum)</td>
<td>Up to 1 mg/dl</td>
</tr>
</tbody>
</table>
Hepatocellular Enzymes.
Hepatocytes contain numerous enzymes that leak into the serum when liver cells die or are damaged.

- Elevations occur in the presence of marked changes in hepatic circulation (e.g., cardiovascular shock) and diseases associated with hepatocellular damage (hepatitis, cirrhosis, inflammatory diseases, and infiltrative hepatic diseases).
- However, serum enzymes may not be markedly elevated in severe, chronic, end-stage liver disease (i.e., the liver is “burned out”).
- **Very high elevations** (more than 20 times normal) are associated with viral or toxic hepatitis.
- **Moderately high elevations** (3 to 10 times normal) are associated with infectious mononucleosis, chronic active hepatitis, extrahepatic bile duct obstruction, and intrahepatic cholestasis.
- **Modest elevations** (1 to 3 times normal) are associated with pancreatitis, alcoholic fatty liver, biliary cirrhosis, and neoplastic infiltration.

**Alanine Aminotransferase (ALT).**
found in high concentrations in hepatocytes and is considered a specific marker of hepatocellular damage.

<table>
<thead>
<tr>
<th>Alanine aminotransferase (ALT)</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Female (Serum)</td>
<td>7-30 U/L</td>
<td></td>
</tr>
<tr>
<td>Male (Serum)</td>
<td>10-55 U/L</td>
<td></td>
</tr>
</tbody>
</table>

**Aspartate Aminotransferase (AST).**
found in hepatocytes, myocardial muscles, skeletal muscle, the brain, and the kidneys. It is used as a nonspecific marker of hepatocellular damage.

<table>
<thead>
<tr>
<th>Aspartate aminotransferase (AST)</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Female (Serum)</td>
<td>9-25 U/L</td>
<td></td>
</tr>
<tr>
<td>Male (Serum)</td>
<td>10-40 U/L</td>
<td></td>
</tr>
</tbody>
</table>

**Gamma Glutamyl Transpeptidase (GGT).**
- found in hepatobiliary, pancreatic, and kidney cells.
- It is elevated in most hepatocellular and hepatobiliary diseases, although elevations correlate better with obstructive disease than with pure hepatocellular damage.
- An elevated GGT level is an early indicator of alcoholic liver disease.

| Gamma glutamyl transpeptidase (GGT) | (Serum) | 1-60 U/L |
Lactic Dehydrogenase (LDH).
- found in the heart, brain, erythrocytes, kidneys, liver, skeletal muscle, and ileum.
- Elevations occur during shock syndrome (marked changes in circulation) and diseases associated with hepatocellular damage (hepatitis, cirrhosis, inflammatory disease, and infiltrative diseases).

| Lactic dehydrogenase (LDH) | (Serum) | 110-210 U/L |
HEMATOLOGIC SYSTEM

ABO Blood Typing.
The antigenic properties of blood are typed to avoid potentially lethal transfusion reactions. Blood types include A, B, AB, and O.

Blood Smear.
The blood smear is produced by smearing a drop of peripheral blood on a slide and examining the smear microscopically. The blood smear is used to obtain a WBC count and differential, to estimate the platelet count, and to evaluate RBC morphology.

Coagulation Tests.
The common tests of coagulation include the bleeding time, PTT, PT, and thrombin time.

- Activated Partial Thromboplastin Time (aPTT).
  assesses the intrinsic clotting pathway (i.e., factors II, V, VIII, IX, X, XI, and XII). It is commonly used to monitor heparin therapy.

- Bleeding Time.
  is the duration of bleeding after a standardized skin incision. It is used to evaluate platelet quantity and function.
• **Prothrombin Time (PT).**
  - It is used to assess the extrinsic and common clotting pathways (i.e., factors II, V, VII, and X and fibrinogen).
  - It is used to monitor warfarin therapy and to assess hepatic synthetic function.
  - The international normalized ratio (INR) is a more standardized expression of PT that takes into account differences in reagent activity. It is calculated according to the equation:

\[
\text{INR} = \left( \frac{\text{PT}_{\text{patient}}}{\text{PT}_{\text{normal}}} \right)^{\text{ISI}}
\]

where
  - PT patient is the patient's PT result expressed in seconds.
  - PT normal is the laboratory's geometric mean value for normal patients expressed in seconds.
  - ISI is the International Sensitivity Index determined for each batch of thromboplastin reagents by manufactures.

| Prothrombin time (PT) | (Plasma) | 8.8-11.6 sec |

- **Thrombin Time.**
  - It is used to evaluate the effect of heparin and thrombolytic drug therapy and coagulation abnormalities.

| Thrombin time | (Plasma) | Control ± 5 sec |

**Complete Blood Count.**
The complete blood count (CBC) consists of the hemoglobin, hematocrit, RBC count, WBC count, mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration.

**LABORATORY TESTS BY SPECIFIC CELL TYPE**

**Platelets.**
- Platelets initiate hemostasis.
- The risk of spontaneous bleeding is greatly increased if the platelet count is less than 20,000 cells/mm³.
- The platelet count is decreased if:
  - the bone marrow fails to produce platelets (as in aplastic anemia, leukemia, and some viral infections)
  - peripheral platelet destruction (as in idiopathic thrombocytopenic purpura, some collagen vascular diseases,
thrombotic thrombocytopenic purpura, disseminated intravascular coagulation, and hemolytic uremic syndrome).

- The platelet count may be increased:
  - after splenectomy
  - in some myeloproliferative diseases, such as myelogenous leukemia and essential thrombocythemia
  - in chronic inflammatory diseases, malignancy, and chronic infections.

- Platelet function is impaired by drugs such as aspirin, dipyridamole, and nonsteroidal antiinflammatory drugs and by disease states such as uremia, multiple myeloma, and severe liver disease.

<table>
<thead>
<tr>
<th>Platelet count (Whole Blood)</th>
<th>150-350×10^3/mm3</th>
</tr>
</thead>
</table>

**Erythrocyte Sedimentation Rate (ESR)**

- It is a nonspecific indicator of inflammation.
- This test measures the rate at which RBCs settle out of mixed venous blood. The settling rate, influenced by the shape of the RBC and the charges on the membrane, is used as a nonspecific marker of inflammatory and malignant disease.

<table>
<thead>
<tr>
<th>Erythrocyte sedimentation rate</th>
<th>Female (Whole Blood)</th>
<th>1-30 mm/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (Whole Blood)</td>
<td></td>
<td>1-13 mm/hr</td>
</tr>
</tbody>
</table>

**Hematocrit.**

- It is the number of RBCs in 100 ml of blood reported as a percentage.
- Reference ranges vary with age, gender, and elevation above sea level.
- increased in vitamin B₁₂ and folic acid deficiencies.
- decreased in iron deficiency.
- used to diagnose anemia and assess the patient’s response to replacement therapy.

<table>
<thead>
<tr>
<th>Hematocrit</th>
<th>Female (Whole Blood)</th>
<th>37%-48%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (Whole Blood)</td>
<td></td>
<td>42%-52%</td>
</tr>
</tbody>
</table>

**Hemoglobin.**

- Hemoglobin is the oxygen-carrying RBC protein.
- Reference ranges vary with age, gender, and elevation above sea level.
- decreased in blood loss and iron deficiency anemia.
- used to diagnose anemia, assess the patient’s response to replacement therapy, and estimate oxygen content.

<table>
<thead>
<tr>
<th>Hemoglobin</th>
<th>Female (Whole Blood)</th>
<th>12-16 g/dl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (Whole Blood)</td>
<td></td>
<td>13-18 g/dl</td>
</tr>
</tbody>
</table>
Iron Metabolism

- **Ferritin.**
  Serum ferritin does not contain iron but is in equilibrium with tissue ferritin, making it a useful indicator of tissue iron stores. It is used to diagnose iron deficiency anemia.

| Ferritin (Serum) | >20 ng/ml |

- **Iron.**
  Serum iron levels are decreased in iron deficiency anemia, chronic infections, and some malignancies. Serum iron levels may be increased in iron poisoning and hemolysis.

| Iron (Serum) | 50-150 μg/dl |

IMMUNOLOGIC SYSTEM

**Coombs’ Test.**
The Coombs’ test uses an antiserum containing antibodies that bridge antibody- or complement-coated RBCs; bridging causes agglutination (clumping).

- **Direct Coombs’ Test.** The direct Coombs’ test uses antibodies directed against human proteins (primarily IgG and C3) to detect whether these proteins are attached to the surface of RBCs. The direct Coombs’ test is used to differentiate between immunologic (e.g., autoimmune) and nonimmunologic (e.g., drug-induced) hemolytic anemias.

- **Indirect Coombs’ Test.** The indirect Coombs’ test detects antibodies against human RBCs in the patient’s serum. It is used in crossmatching before transfusion.

INFECTIONOUS DISEASE

**Acid-Fast Stain.**
The acid-fast stain is used to screen for the presence of Mycobacterium, Nocardia, and Legionella species in body tissues and fluids. Some oocysts, such as Cryptosporidium, can be detected with the acid-fast stain.
Cold Agglutinins. 
Cold agglutinins are antibodies that bind to the surface of RBCs and agglutinate when the blood sample is cooled. About 50% of patients with *Mycoplasma pneumoniae* have cold agglutinin titers.

Minimum Inhibitory Concentration. 
The minimum inhibitory concentration (MIC) is the lowest antibiotic concentration that completely inhibits the visible growth of a microorganism. It is used to determine the susceptibility of the organism to antibiotics.

Potassium Hydroxide Preparation. 
Potassium hydroxide (KOH) 10% to 20% is used to detect fungi in body fluids and skin scrapings.

White Blood Cell Count and Differential. 
The WBC count is often elevated in patients with bacterial and viral infections. A left shift (increased bands and segmented neutrophils) indicates a bacterial infection. The lymphocyte count may be elevated in viral infections. The eosinophil count may be elevated in parasitic infections. Elderly patients and those with impaired immune systems or very severe infectious diseases may not be able to mount a white cell response to infection.

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**RENAL SYSTEM**

Urinalysis. 
Urinalysis is used to screen for renal and nonrenal disease and to monitor the patient’s response to drug and nondrug therapy.31,32 The urinalysis consists of macroscopic assessment, chemical screening by dipstick, and microscopic assessment of the urine sediment. Quantitative analyses are performed when indicated.

Dipstick Screening. Multiple-reagent strips are used to determine the urinary pH and specific gravity and to screen for the presence of bilirubin, blood, glucose, ketones, leukocyte esterase, nitrites, pH, protein, and urobilinogen.

- **Bilirubin.** Bilirubin is not normally present in the urine. It is excreted in the urine in the presence of severe liver disease or obstructive biliary disease. The urine appears dark yellow to brown if bilirubin is present.

- **Blood.** Blood is not normally present in the urine. The urine may be visibly bloody, or blood may be found on microscopic or dipstick examination. A variety of renal and nonrenal diseases, including urinary tract infections, renal stones, sickle cell disease, glomerulonephritis, and malignant hypertension, are associated with blood in the urine.
- **Glucose.** Glucose is not normally present in the urine. Urine glucose may be present in diabetes mellitus.

- **Ketones.** Ketones are not normally present in the urine. Urinary ketones may be present before serum ketones are detectable in diabetic ketoacidosis and may be found in patients who are dieting or are malnourished.

- **Leukocyte Esterase.** Leukocyte esterase is not normally present in the urine. This enzyme is present in WBCs and may be found in the urine during urinary tract and vaginal infections.

- **Nitrites.** Nitrites are not normally present in the urine. Escherichia coli converts dietary nitrates to nitrites. Urinary nitrites are associated with E. coli urinary tract infections but may only be found if the urine is retained in the bladder for at least 4 hours.

- **pH.** The urinary pH reflects the overall acid-base balance of the body and the kidneys’ ability to handle acids and bases. The formation of kidney stones is pH dependent. An alkaline pH (pH >7.0) is commonly associated with the presence of urea-splitting organisms such as Proteus mirabilis.

- **Protein.** Small amounts of protein are normally present in the urine (as much as 0.5 g/day). Urinary protein is increased in a variety of renal diseases.

- **Specific Gravity.** The specific gravity reflects the kidneys’ ability to concentrate urine and the overall state of hydration. The greater the concentration of the urine is, the higher the specific gravity is.

- **Urobilinogen.** Urobilinogen is not normally present in the urine. It may be excreted in the urine in the presence of severe liver disease or obstructive biliary disease.
RESPIRATORY SYSTEM

** Forced Expiratory Volume in 1 Second. **
The forced expiratory volume in 1 second (FEV1) is the volume of air (in liters) exhaled during forced exhalation after maximal inspiration. Normally, at least 80% of the forced vital capacity (FVC) is exhaled in the first second. The FEV1 is used with the FVC to differentiate between obstructive (FEV1/FVC <80%) and restrictive (reduced FEV1 and FVC but normal FEV1/FVC relationship) lung disease. An FEV1 of less than 1 L indicates significant lung disease.

** Forced Vital Capacity. **
The FVC is the volume of air (in liters) blown out of the lungs during forced exhalation after maximal inspiration. It is used with the FEV1 to differentiate between obstructive and restrictive lung disease (see preceding FEV1 discussion).

** Peak Expiratory Flow Rate. **
The peak expiratory flow rate (PEFR) measures the forced expiratory flow in liters per minute. It is used to monitor the progression and response to therapy of patients with bronchospastic diseases such as asthma. Asthmatic patients monitor their PEFR at home with inexpensive handheld peak flowmeters. PEFR variability of greater than 30% indicates moderate to severe persistent asthma.

** Residual Volume. **
The residual volume (RV) is the volume of air remaining in the lungs after forced expiration. It is measured with body plethysmography. RVs are increased in diseases characterized by small airway obstruction.

** Tidal Volume. **
The tidal volume (VT) is the volume of air inspired or expired with normal breathing.