ASSISTING IN THE ANALYSIS OF BLOOD

SCENARIO

Dana Cummings is a certified medical assistant working in the Westhills Family Practice Center. She is preparing to collect blood from Mr. Corrigan, who recently underwent renal transplantation because of complications from diabetes type 1. He has come to the office today for a routine examination. Dr. Fischbach suspects that Mr. Corrigan is anemic and orders an anemia panel in addition to a renal panel; a hemoglobin A1c level; a complete blood count, including hemoglobin, hematocrit, and differential; prothrombin time (PT); and alanine aminotransferase/aspartate aminotransferase (ALT/AST) testing.

While studying this chapter, think about the following questions:

- Why are so many tests being performed for Mr. Corrigan?
- Which of these tests probably will be completed today in the office laboratory?

LEARNING OBJECTIVES

1. Define, spell, and pronounce the terms listed in the vocabulary.
2. Apply critical thinking skills in performing the patient assessment and patient care.
3. Name four main functions of blood.
4. Identify the role of the hematology laboratory in patient care.
5. Describe the appearance and function of erythrocytes.
6. Describe the appearance and function of granulocytic and agranulocytic leukocytes.
7. Differentiate between T cells and B cells.
8. Describe the appearance and function of thrombocytes.
9. Explain the process of clot formation.
10. Identify the anticoagulant of choice for hematology testing.
11. Explain the purpose of the microhematocrit test.
12. Perform a microhematocrit test.
13. Explain the role of hemoglobin in the body.
15. Identify the tests included in a complete blood count (CBC) and their reference ranges.
16. Explain the process of automated blood cell counting.
17. Distinguish between normal and abnormal test results.
18. Describe the red blood cell (RBC) indices and how they are calculated.
19. Explain the reasons for performing a white blood cell (WBC) differential.
20. Discuss the Wright's stain sequence.
21. Describe the appearance of normal erythrocytes.
22. Describe the appearance of the five different types of leukocytes seen in a normal Wright-stained differential.
23. Cite the reasons for performing an erythrocyte sedimentation rate test.
24. Describe the sources of error for the erythrocyte sedimentation rate test.
25. Determine an erythrocyte sedimentation rate using a modified Westergren method.
26. Describe the tests performed to assess coagulation.
27. Differentiate between the ABO blood groupings and the Rh blood groupings.
28. Secure a capillary blood sample and determine the ABO and Rh grouping of the sample.
29. Discuss rare blood types and the implication of having a rare blood type when transfusion is necessary.
30. Describe the methodology behind the clinical chemistry testing methods used in the physician's office laboratory.
31. Explain the reasons for testing blood glucose, blood cholesterol, hemoglobin A1c, thyroid hormone levels, and liver enzymes.
32. Perform a cholesterol test using a cholesterol monitor approved by the U. S. Food and Drug Administration (FDA).
33. Summarize typical chemistry panels, the reason for performing each panel, and the individual tests performed in those panels.
VOCABULARY

anemia A condition caused by deficiency of red blood cells (RBCs).
artifacts Structures or features not normally present but visible as a result of an external agent or action, such as in a microscopic specimen after fixation or in a radiographic image.
centrifuge (sen'-truh-fuuj) An apparatus consisting essentially of a compartment that spins about a central axis to separate contained materials of different specific gravities or to separate colloidal particles suspended in a liquid.

enzymes Complex proteins produced by cells that act as catalysts in specific biochemical reactions.
polycythemia vera (pah-lee-si-the'-me-uh/veh'-rah) A condition marked by an abnormally large number of red blood cells (RBCs) in the circulatory system.
type and cross-match Tests performed to assess the compatibility of blood to be transfused.
urea The major nitrogenous end-product of protein metabolism and the chief nitrogenous component of the urine.

HEMATOLOGY

The hematology section of a laboratory deals with counting RBCs, white blood cells (WBCs), and platelets; differentiating WBCs on stained blood smears; measuring the percentage of RBCs in the blood (hematocrit); and determining the oxygen-carrying capacity of the blood (hemoglobin).

The complete blood cell count (CBC) is the laboratory procedure most frequently ordered for blood specimens. It gives a fairly complete look at the components of blood and can provide a wealth of information about a patient's condition. It routinely includes:

- RBC count
- WBC count
- Hemoglobin determination
- Hematocrit determination
- Differential WBC count
- Estimation of platelet numbers
- Red cell indices

CRITICAL THINKING APPLICATION 54-1

- Dana will collect the specimen for Mr. Corrigan's CBC. What tests are included in the CBC? Can any of these tests be performed by capillary puncture? Explain.
- Which vacuum tube will Dana use to collect the CBC sample?

Whole blood is composed of formed elements suspended in a clear, yellow, liquid portion called plasma. Plasma makes up approximately 55% of blood by volume. The remaining 45% consists of formed cellular elements: the erythrocytes (RBCs), leukocytes (WBCs), and thrombocytes (platelets). These cellular elements all have special functions.

Erythrocytes

RBCs, or erythrocytes, are formed in the red bone marrow of the ribs, sternum, pelvis, and skull and in the ends of long bones in adults. The nucleus of the immature form of the RBC disintegrates as the cell matures. Loss of the nucleus results in the
familiar shape of the RBC: a biconcave disk that is thicker at the rim than in the middle. Erythrocytes transport oxygen from the lungs to the body cells and carry carbon dioxide away from cells, back to the lungs to be exhaled. The main constituent is the red pigment hemoglobin, which is composed of iron and protein. Hemoglobin actually carries oxygen and some carbon dioxide throughout the body.

The life span of an erythrocyte is approximately 120 days. As the cell nears the end of its life, it becomes more fragile and eventually ruptures and breaks. The iron is reused for the formation of new RBCs, and the protein is converted into a bile pigment.

### Leukocytes

WBCs, or leukocytes, have a nucleus and are larger than erythrocytes. The prime function of the leukocyte is to protect the body against infection and disease. The five types of leukocytes are classified as granular or agranular. Granular leukocytes, or polymorphonuclear leukocytes, include the neutrophils, eosinophils, and basophils. They are characterized by their heavily granulated cytoplasm and segmented nuclei. The agranular leukocytes are the lymphocytes and monocytes, both of which have clear cytoplasm and a solid nucleus.

Granular leukocytes are phagocytic; that is, they engulf invading bacteria and viruses. Unlike erythrocytes, leukocytes function in the tissues. During inflammation, the blood carries the WBCs through dilated vessels to the site of injury. Capillary walls become more permeable, and granular cells squeeze through by ameboid motion. Once at the site of infection or injury, the cells engulf the invading microorganism, creating pus, which contains dead leukocytes, bacteria, and tissue cells.

Agranular leukocytes produce antibodies. The lymphocytes are classified as T cells or B cells, based on their functional characteristics.

### T Cells

T cells make up about 65% to 80% of circulating lymphocytes and have a life span of months to years. This is important for conferring long-lasting immunity to microbial infections. T cells mount the immune response to intracellular parasites, viruses, fungi, and bacteria. Delayed hypersensitivity reactions, such as the response to poison ivy, are controlled by T-cell defenses, as is organ transplant rejection. T cells are subdivided into several types, based on their function:

- **Cytotoxic (killer) T cells**: These cells kill foreign, virus-infected, and tumor cells. They produce proteins called perforins that induce cell death by punching holes in the cell membrane.
- **Helper T cells**: These are the most numerous type of T cell. They stimulate the activity of other T cells.
- **Suppressor T cells**: These cells inhibit the activity of other T cells.
- **Memory T cells**: These cells, which have a long life span, respond quickly to presentation of the same antigen at a later date.
- **Natural killer cells**: These cells kill virus-infected cells and tumor cells without previous sensitization.

### B Cells

B cells are formed in bone marrow and then migrate to other lymph organs, where they multiply and reside. When stimulated, B cells differentiate into plasma cells that produce specific antibodies to an antigen. Antibodies circulate in the plasma or are present in secretions. Some antibodies cause cells to clump and precipitate, whereas others activate the complement system. The complement system is a series of reactions between plasma proteins that amplifies the immuneologic response to foreign molecules. Activation of the complement system leads to the lysis of microorganisms or their phagocytosis by neutrophils.

Antibodies are protein molecules that attach to antigens. Very small antigens, such as toxins and viruses, can be directly neutralized by antibodies; larger antigens, such as bacteria, require the help of agranular leukocytes. Three steps are required to destroy these pathogens:

1. **Antigen processing**: When a macrophage phagocytizes bacteria, proteins (antigens) from the bacteria are broken down into smaller molecules, which are then "displayed" on the macrophage's surface, attached to special molecules called major histocompatibility complex class II (MHC II) molecules. Bacterial proteins are similarly processed and displayed on MHC II molecules on the surface of B lymphocytes.
2. **Lymphocyte stimulation**: When a T lymphocyte "sees" the same peptide on the macrophage and on the B cell, the T cell stimulates the B cell to turn on antibody production.
3. **Antibody production**: The stimulated B cell undergoes repeated cell divisions, enlargement, and differentiation to form a clone of antibody-secreting plasma cells. Hence, through specific antigen recognition of the invader, clonal expansion, and B-cell differentiation, an effective number of plasma cells is acquired, all secreting the same needed antibody. That antibody then binds to the bacteria, making them easier for the white cells to ingest. Antibody combined with a plasma component called complement may also kill the bacteria directly.

### Thrombocytes

Thrombocytes are not true cells, but rather cytoplasmic fragments of a megakaryocyte, a large cell in the bone marrow. They are the smallest formed elements of the blood. They typically have a discoid shape; however, when activated, they become globular and form fingerlike cytoplasmic extensions called pseudopodia.

### Clot Formation

In minor injuries, thrombocytes tend to collect and form plugs in blood vessel openings. To control bleeding from vessels larger than capillaries, a clot must form at the point of injury. Coagulation of the blood also is initiated by blood platelets. The platelets produce a substance that combines with calcium ions in the blood to form thromboplatin, which in turn converts the protein prothrombin into thrombin in a complex series of reactions. Thrombin, an enzyme, converts fibrinogen, a protein substance, into fibrin, an insoluble protein that forms an intricate network of minute, threadlike structures called fibrils, and causes the
blood plasma to gel. The blood cells and plasma become enmeshed in the network of fibrils, forming a clot.

Blood clotting can be initiated by the extrinsic mechanism, in which substances from damaged tissues are mixed with the blood, or by the intrinsic mechanism, in which the blood itself is traumatized. More than 30 substances in blood have been found to affect clotting; whether blood will coagulate depends on a balance between the substances that promote coagulation (procoagulants) and those that inhibit it (anticoagulants). Coagulation of blood within blood vessels in the absence of injury can cause serious illness or death, especially when a clot forms in the coronary arteries (thrombosis) or cerebral arteries (stroke).

Hemophilia, a bleeding disorder, occurs when a person has a mutation in one of the clotting factor genes. It is a hereditary, gender-linked disorder that affects males of all races and ethnic groups. The mutated gene is on the X chromosome inherited from the mother. Approximately one in 4,000 males is born with the disorder; it is rare, but possible, for a female to have hemophilia. People with hemophilia inject themselves with purified clotting factor to prevent bleeding episodes. Internal bleeding, particularly in the joints, is a problem despite treatment and leads to painful arthritis.

### Plasma

Plasma is a highly complex liquid that is the carrier for the formed elements and other substances, such as proteins, carbohydrates, fats, hormones, enzymes, mineral salts, gases, and waste products. Plasma is composed of approximately 90% water, 9% protein, and 1% various other chemical substances. When plasma proteins and other components are used up during the clotting process, the remaining liquid is called *serum*.

### Collection of Blood Specimens

For most hematology tests, an adequate blood sample can be obtained from capillaries by finger puncture. If a larger sample is required, blood can be obtained from a vein by venipuncture. For a CBC, venous blood is collected in a tube containing an anticoagulant that prevents clotting. Ethylenediamine tetraacetic acid (EDTA) is the anticoagulant of choice for hematology testing. It is important to prevent blood from being hemolyzed during collection for hematology testing.

### Hematocrit

The hematocrit (Hct) is a measurement of the percentage of packed RBCs in a volume of blood. The spun microhematocrit test is based on the principle of separating the cellular elements from plasma by centrifugation (Procedures 54-1 and 54-2). Two or three drops of blood are collected in a capillary puncture in two capillary tubes and are placed in a specially designed microhematocrit centrifuge (Figure 54-1). Alternatively, the capillary tubes can be filled with EDTA-anticoagulated blood from a lavender-topped vacuum tube. Capillary tubes can either be preplugged or open and may be made of glass or plastic. If the tube is not plugged, it must be sealed with a special clay before centrifugation.

After centrifugation, RBCs are at the bottom of the tube, WBCs and platelets are in the center, and plasma is on top (Figure 54-2). From this separation the microhematocrit is determined by comparing the concentration of RBCs to the total volume of the whole blood sample. The percentage is read by placing the tubes on a special microhematocrit reader. Some microhematocrit centrifuges have a built-in reading scale that reads calibrated capillary tubes. Microhematocrits should be performed in duplicate and the average of the two results reported.

Inverness Medical Professional Diagnostics (formerly Wampole, Princeton, New Jersey) manufactures a CLIA-waived instrument that uses electrical conductivity to determine the hematocrit. The STAT-CRIT hct is a self-contained, portable unit that determines
PROCEDURE 54-1

Perform Hematology Testing: Perform a Microhematocrit Test

GOAL: To perform a microhematocrit test accurately.

EQUIPMENT and SUPPLIES
- Fresh sample of blood collected in a tube containing EDTA anticoagulant
- Capillary tubes
- Sealing clay
- Centrifuge
- Disposable gloves
- Protective eyewear
- Biohazardous waste container
- Patient's record

PROCEDURAL STEPS

1. Sanitize your hands. Put on nonsterile gloves and protective eyewear.
   PURPOSE: To ensure infection control.
2. Assemble the materials needed.
3. Fill two plain (blue tipped) capillary tubes two-thirds to three-fourths full with well-mixed blood by tipping the blood tube slightly and touching the capillary tube end opposite the blue band to the blood. If the capillary tube and the blood tube are held almost parallel to the table, the capillary tube fills easily by capillary action.
   PURPOSE: Duplicates should always be done as a means of quality control. Tubes are not filled completely to provide space for the sealing clay.
4. Wipe the outside of the tube with clean gauze without touching the wet open end of the tube.
   PURPOSE: Wiping the capillary tube removes any blood. Touching the blood with absorbent material removes more plasma than blood cells and can alter the hematocrit.
5. Tip the tube until the blood runs toward the end with the colored band.
   PURPOSE: This prevents blood from accidentally being removed from the tube.
6. Seal the end with the blue band with sealing clay by holding the tube horizontally and inserting the tube. Insert the tube as many times as needed to achieve a plug up to the blue band (Figure 1).
   PURPOSE: This prevents the clay from becoming contaminated with blood, helps prevent leakage of blood, and keeps the gasket in the centrifuge from being cut by the capillary tubes.
7. Place the tubes opposite each other in the centrifuge with the sealed ends securely against the gasket (see Figure 54-1).
   PURPOSE: The centrifuge must always be balanced to prevent damage. If the clay ends of the capillary tubes are not outermost against the gasket, the sample will spin out of the tubes, contaminating the centrifuge.
8. Note the numbers on the centrifuge slots and record them.
   PURPOSE: The sample must be identified throughout the entire procedure.
9. Secure the locking top, fasten the lid down, and lock.
   PURPOSE: If the locking top is not firmly in place during the spinning cycle, the tubes will come out of their slots and break. The lid is always locked during centrifugation for safety purposes; that is, to prevent aerosols or broken glass from being ejected.
10. Set the timer and adjust the speed as needed.
    PURPOSE: The prescribed time is 3 to 5 minutes at 11,000 to 12,000 rpm. Check the manufacturer's instructions for time and speed.
11. Allow the centrifuge to come to a complete stop. Unlock the lids.
    PURPOSE: Opening the centrifuge before it has stopped could result in harm to the user.
12. Remove the tubes immediately and read the results. If this is not possible, store the tubes in an upright position.
    PURPOSE: Tubes left in the centrifuge will show altered results, because the red blood cell (RBC) layer spreads horizontally.
13. Determine the microhematocrit values using one of the following methods:
   a. Centrifuge with built-in reader using calibrated capillary tubes.
      - Position the tubes as directed by the manufacturer's instructions.
      - Read both tubes.
      - The average of the two results is reported.
      - The two values should not vary by more than 2%.
   b. Centrifuge without built-in reader.
      - Carefully remove the tubes from the centrifuge.
      - Place a tube on the microhematocrit reader.
      - Align the clay-RBC junction with the zero line on the reader. Align the plasma meniscus with the 100% line. The value is read at

FIGURE 1  (From Rodak B: Hematology: clinical principles and applications; ed 3, St Louis, 2007, Saunders.)
TABLE 54-1 Hematocrit (Hct) Reference Values

<table>
<thead>
<tr>
<th>Age and/or Gender</th>
<th>Hct Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonate</td>
<td>44-64</td>
</tr>
<tr>
<td>Infant, 1 mo</td>
<td>35-49</td>
</tr>
<tr>
<td>Infant, 6 mo</td>
<td>30-40</td>
</tr>
<tr>
<td>Child, 1-10 yr</td>
<td>35-41</td>
</tr>
<tr>
<td>Adult, Men</td>
<td>42-52</td>
</tr>
<tr>
<td>Adult, Women</td>
<td>36-45</td>
</tr>
</tbody>
</table>


the hematocrit in 30 seconds. The testing methodology is based on the principle that blood is a conducting medium in which RBCs act as resistors. The plasma conducts electricity based on temperature. The more erythrocytes in a sample, the more resistance is recorded. A blood sample is introduced into the sample carrier, which has a thin, plastic membrane that permits rapid equilibration of the temperature of the blood and the measuring port. This instrument is best used with fresh blood obtained from a finger stick; anticoagulants can interfere with conductivity, and heparin, not EDTA, is the anticoagulant of choice.

The hematocrit also can be calculated using the RBC count and RBC size values from an automated cell counter.

Normal Hct values vary with gender and age (Table 54-1). They range from a low of 36% in women to a high of 52% in men. Low microhematocrit values can indicate anemia or the presence of bleeding in a patient; high values may be caused by dehydration or a condition such as polycythemia vera. Values can be influenced by physiologic or pathologic factors and by collection techniques.

The microhematocrit is a commonly performed test requested by physicians separately or as part of the CBC. Because it is a simple procedure that requires only a small amount of blood, it is an ideal screening test and often is part of a routine physical examination.

HEMOGLOBIN

The hemoglobin (Hgb) determination is a rough measure of the oxygen-carrying capacity of blood. The hemoglobin concentration can be determined as part of the CBC or as an individual test. Many methods of determining the hemoglobin concentration have been used over the years. The earliest measures simply involved comparing the color of a drop of blood to a chart. Dark red blood has more hemoglobin than pale red blood. The international reference, or "gold standard," methodology for hemoglobin determination is the hemoglobin-cyanide or cyanmethemoglobin (HiCN) method. A sample of whole blood is diluted in Drabkin’s reagent, which contains cyanide. The RBCs lyse, releasing hemoglobin, which reacts with cyanide to form hemoglobin-cyanide. The sample is then placed in a colorimeter, and the amount of light absorbed by the sample at a 540-nm wavelength is determined.

A hemoglobinometer is a colorimeter that determines hemoglobin by measuring the amount of light absorbed by a sample of blood in which the hemoglobin has been released and chemically modified.
PROCEDURE 54-2

Perform Routine Maintenance of Clinical Equipment: Perform Preventive Maintenance for the Microhematocrit Centrifuge

GOAL: To perform daily, monthly, and quarterly quality control on a microhematocrit centrifuge.

EQUIPMENT and SUPPLIES

- Microhematocrit centrifuge
- Quality control logbook
- High-, normal-, and low-quality control samples
- Utility gloves
- Disposable gloves
- Face shield, moisture-proof gown as needed
- Disinfectant
- Biohazardous waste container
- Maintenance logbook

PROCEDURAL STEPS

NOTE: These are generic recommendations. Always check the manufacturer’s guidelines for specific instructions. Always unplug the power cord before cleaning or servicing the centrifuge. Wear protective clothing and gloves, as well as a face shield.

Daily Maintenance
1. Clean the inside of the centrifuge and the gasket with a disinfectant recommended by the manufacturer. Plastic and nonmetal parts may be cleaned with a fresh solution of 5% sodium hypochlorite (bleach) mixed 1:10 with water (one part bleach plus nine parts water).
   PURPOSE: To remove any dried blood or shattered glass. Do not use bleach on the gasket, because it may harden the rubber.

Monthly Maintenance
1. Check the reading device. Misuse and zeroing of the reading devices can promote considerable error. Always use a second, simple reading device as a cross-check. Use a ruler or a flat plastic card specially made for this purpose. To use these cards, lay the spin hematocrit tube on the card and align the red cells with a line on the card to obtain the reading.

2. Check the rotor for cracks or corrosion and check the interior for signs of white powder.
   PURPOSE: Cracks, corrosion, or powder may indicate impending rotor failure; they require the immediate attention of a service technician.

3. Record all preventive maintenance in the laboratory logbook.
   PURPOSE: Recording maintenance is necessary to maintain warranties and to comply with regulations established by the Clinical Laboratory Improvement Amendments (CLIA) and other regulatory agencies.

Semiannual Maintenance
1. Check the gasket for cuts and breaks.
   PURPOSE: Cut gaskets allow tubes to leak and must be replaced.

2. Check the timer with a stopwatch.

3. Perform a maximum cell pack to verify the time required for complete packing by reading a sample after centrifugation and then recenterfuging for 1 minute. The results should be the same. If they are not, perform preventive maintenance and/or call the service technician.
   PURPOSE: If the cells compact further during recenterfugation, the centrifuge is not rotating at the proper speed, and hematocrit results will be falsely elevated.

4. Record all preventive measures in the laboratory logbook.
   PURPOSE: Recording maintenance is necessary to maintain warranties and to comply with regulations established by CLIA and other regulatory agencies.

Annual Maintenance (or Maintenance Performed as Needed)
1. The centrifuge functions and maintenance verification should be performed by qualified personnel. This includes checking the centrifuge mechanism, rotors, timer, speed, and electrical leads.

2. Record all professional service calls in the laboratory logbook.

CLIA-waived methods include the STAT-Site M Hgb (Stanbio Laboratories, Boerne, Texas), a completely portable, battery-operated hemoglobin analyzer that fits in the palm of the hand (Figure 54-3), and the HemoCue (HemoCue AB, Angelholm, Sweden) (Procedure 54-3). The HemoCue uses plastic cuvettes that contain sodium deoxycholate, sodium nitrite, and sodium oxalate. The sodium deoxycholate lyses the erythrocytes in the sample, releasing the hemoglobin, which reacts with sodium nitrite to form methemoglobin. The methemoglobin reacts with the sodium oxide to form azidemethemoglobin, which can be detected at two different wavelengths, 570 and 880 nm. Two wavelengths are used to compensate for possible turbidity in the sample. Capillary, venous, or arterial blood can be used in the cuvette, and cuvettes have a long shelf life.

The copper sulfate method is a CLIA-waived manual method of hemoglobin determination that is often used to screen blood donors. It is based on the principle of specific gravity; when a drop of blood from a patient with normal hemoglobin values is dropped into a copper sulfate solution, it falls rapidly to the bottom (Figure 54-4). If the drop falls slowly or not at all, hemoglobin levels are below reference range.

Normal hemoglobin values vary throughout life. They normally are quite high at birth, decline during childhood, and then increase through the teens until adult levels are reached (Table 54-2). Values range from a low of 12 g/dL in women to a high of 17.5 g/dL in men. The various factors that affect the hemoglobin level include age, gender, diet, altitude, and disease.

The hemoglobin and hematocrit tests often are performed together and are referred to as an "H&H." A quick mental calculation should always be done before reporting H&H results: Hemoglobin value × 3 ± 3 should equal the hematocrit value.
For example, if the hemoglobin is 15 g/dL, the hematocrit should be 42% to 48%.

**CRITICAL THINKING APPLICATION 54-2**

Mr. Corrigan’s hematocrit value is 37%. What does Dana calculate as the expected hemoglobin value? Does this test confirm the doctor’s suspicions of anemia?

**RED BLOOD CELL COUNT**

The RBC count is a commonly performed procedure and is part of the CBC (Table 54-3). It approximates the number of circulating RBCs. The function of RBCs is to transport oxygen to tissues. The condition in which the oxygen-carrying capacity of blood is below normal is called anemia. The RBC count often is decreased in anemia. Increases are found in people with dehydration, polycythemia vera, or severe burns and in those who live at high altitudes, in whom it is an adaptation to the lower oxygen content of the air.

Normal RBC values range from 4 million to 6 million cells/mm³. RBC counts usually are higher in males than in females.

**WHITE BLOOD CELL COUNT**

The WBC count gives an approximation of the total number of leukocytes in circulating blood. The count is performed to help the physician determine whether an infection is present or to aid in the diagnosis of leukemia. It also may be used to follow the course of a disease and to determine whether the patient is responding to treatment.

The normal WBC count varies with age. It is higher in newborns and decreases throughout life. The average adult range is 4,000 to 11,000 cells/mm³. Many factors affect the WBC count.

**Determing the Red Blood Cell and White Blood Cell Counts**

An increase in the number of normal WBCs is a condition called leukocytosis.

Physiologic increases in the WBC count are seen with pregnancy, stress, anesthesia, exercise, exposure to temperature extremes, and after treatment with corticosteroids. Pathologic causes of leukocytosis include many bacterial infections, leukemia, appendicitis, and pneumonia. A decrease in the WBC count is called leukopenia. This condition may be caused by viral infections or by exposure to radiation and certain chemicals and drugs.
The current availability of many different types of cell counters has made it possible for the physician’s office to become fully automated. Modern instruments range from relatively simple, inexpensive counters to very complex, expensive instruments. Automation improves the accuracy of cell counting and results in greater efficiency. In addition, it reduces the frequency of handling of the individual blood specimen and the risk of exposure to blood-borne pathogens. The operation of the typical counters used in a physician’s office laboratory is considered moderately complex by CLIA standards. It is essential that strict standardization procedures and quality control methods be followed when automated instruments are used to perform blood cell counts.

Most automated cell counters operate by first diluting the cells in a fluid that conducts an electrical current. These diluted cells then pass through a special narrow opening in the instrument. The passing cells interrupt the flow of current, and each interruption is counted. Some instruments use a laser beam instead...
### Table 54-3: Reference Ranges for Complete Blood Count Values

<table>
<thead>
<tr>
<th>TEST</th>
<th>NEONATES</th>
<th>INFANTS (6 mo)</th>
<th>CHILDREN</th>
<th>MEN</th>
<th>WOMEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBCs</td>
<td>4.87-7.1 million/mm³</td>
<td>3.8-5.5 million/mm³</td>
<td>4.5-4.8 million/mm³</td>
<td>4.5-6 million/mm³</td>
<td>4.5-5.5 million/mm³</td>
</tr>
<tr>
<td>Hematocrit (Hct)</td>
<td>44%-64%</td>
<td>30%-40%</td>
<td>35%-41%</td>
<td>42%-52%</td>
<td>36%-45%</td>
</tr>
<tr>
<td>Hemoglobin (Hgb)</td>
<td>17-23 g/dL</td>
<td>9-14 g/dL</td>
<td>11-16 g/dL</td>
<td>15-17 g/dL</td>
<td>12-16 g/dL</td>
</tr>
<tr>
<td>WBCs</td>
<td>9,000-30,000/mm³</td>
<td>6,000-16,000/mm³</td>
<td>5,000-13,000/mm³</td>
<td>4,000-11,000/mm³</td>
<td></td>
</tr>
</tbody>
</table>

#### RBC Indices
- MCV: 96-108 fl
- MCH: 32.34 pg
- MCHC: 31.33 g/dL

#### WBC Differential
- Neutrophils: ≥45% by age 1 wk, 32% for children 2 yr or older, 50%-65%
- Bands: 0%-7%
- Eosinophils: 0%-3%
- Basophils: 0%-1%
- Monocytes: 4-9%
- Lymphocytes: ≥45% by age 1 wk, 61% for children 2 yr or older, 25%-40%
- Platelets: 140,000-300,000/mm³, 200,000-475,000/mm³, 150,000-450,000/mm³, 150,000-400,000/mm³


#### Figure 54-5
Automated cell counter. (Courtesy Coulter, Los Angeles, Calif.)

It is important that medical assistants understand hematology laboratory results and that they are able to distinguish between normal and abnormal levels. Combining what you have learned from hematology diagnostic reference ranges in Table 54-3 and Figure 54-6, which is a sample lab report that identifies this particular lab's reference ranges, answer the following critical thinking exercises.

#### Critical Thinking Application 54-3
Distinguish between normal and abnormal test results in the following patients:
- Maggie McGuire, age 6, has a hematocrit of 38%. Is that normal?
- Carlos Santiago, age 54, has a WBC count of 13,000/mm³, and Dr. Fischbach asks to see his previous blood work. Why?
- Angelina Washington, age 23, has an Hct of 32% and an Hgb of 10 g/dL. Why would she be diagnosed with anemia?
- Rose Conrad has a platelet count of 142,000/mm³. Why is Dr. Fischbach concerned about a bleeding disorder?

#### Red Cell Indices
A variety of calculations can be performed using the information from the CBC to produce indices that provide information about RBC disorders. Opinions vary about the clinical value of red cell indices. They are used to classify anemias and to select additional tests to determine the cause of anemia. They also may be used to monitor the treatment of anemia, because they may change in response to treatment. The standard indices are as follows.
**Mean corpuscular volume (MCV):** On automated cell counters, the MCV is computed using the measurements of each red cell. With manual methods, it is calculated by dividing the hematocrit by the red cell count and multiplying by 10; the unit of measurement is the femtoliter (fL). The MCV measures the size of RBCs and is the most important index for classifying anemias as macrocytic (higher than normal MCV) or microcytic (low MCV). The normal reference range is 82 to 108 fL.

**Mean corpuscular hemoglobin (MCH):** MCH = Hemoglobin + RBC count. The MCH is calculated to give the average weight of hemoglobin in an individual RBC; the unit of measurement is the picogram (pg). The reference range is 26 to 34 pg.

**MCH concentration or content (MCHC):** MCHC = Hemoglobin + Hematocrit. The MCHC indicates the average weight of hemoglobin compared with the cell size. It traditionally is a calculated value, but some instruments may measure the density of the cells as they are counted and compare this value with the calculated value. The reference range is 32 to 37 g/dL. With a decreased MCHC, the RBCs appear pale, or hypochromic, in a stained blood smear. An increased MCHC is rarely a true value and probably represents an error in the measurement of the hemoglobin or hematocrit.

**Red cell distribution width (RDW):** The RDW is the degree of red cell size variation, or how much difference exists between the largest and smallest red cells. The RDW is calculated to provide a measure of the anisocytosis, or variation in size, of the RBCs. The reference range is 9 to 14.5.

### DIFFERENTIAL CELL COUNT

The purpose of the differential, or “dif,” is to analyze and quantitate the types of WBCs found in a sample of blood. The differential can be performed manually using a stained blood smear and a microscope or by an automated instrument. A number of automated cell counters have integrated differential analyzers.
use high-frequency conductivity to gather information about cell size, internal structure, and density; they also have helium-neon lasers coupled with multiple-angle light scatter that provide information about a cell's internal structure, granularity, and surface characteristics.

**Preparation of Blood Smears for the Differential**

A blood smear enables the examiner to view the cellular components of blood in as natural a state as possible. The morphology of leukocytes, erythrocytes, and platelets can be studied, and their size, shape, and maturity can be evaluated.

A blood smear is prepared by spreading a drop of blood on a clean glass slide. The slide must be free of dust and grease. The best specimen for a blood smear is capillary blood that has no anticoagulant added. EDTA-anticoagulated blood can be used, provided the smear is made within 2 hours of collection.

The three kinds of blood smears are the coverglass smear, the spun smear, and the wedge smear. The coverglass smear is often used for bone marrow aspirations and involves placing a drop of blood between two coverslips and quickly pulling them apart. The spun smear uses a centrifuge to distribute the blood on a slide and often has the advantage of being a closed system, in that the blood tube is punctured by the instrument and does not have to be handled by the technician. The wedge smear is used most frequently and involves placing a small drop of blood 1/2 inch from the right end of a glass slide. The end of a second glass spreader slide is placed in front of the drop of blood at an angle of 30 to 35 degrees. The spreader slide is brought back into the drop until the blood spreads along the edge of the spreader slide. This is done with a quick but smooth gliding motion. The spreader slide is then pushed to the left with a quick, steady motion, spreading the blood across the slide.

A good wedge smear should cover half to three fourths of the slide. It should show a gradual transition from a thick to a thin end with a feathered edge. It should have a smooth appearance with no ridges, holes, lines, streaks, or clumps (Figure 54-7). On microscopic examination, the cells should be distributed evenly.

After the smear has been made, it should be allowed to dry. The slide should be propped up to dry with the thick end (heel) down. Do not blow on the slide to dry it. This can cause artifacts in the RBCs from the moisture in your breath. Once dry, the patient's name is written on the frosted end of the slide with a pencil or marker.

After labeling, the slide is fixed in methanol, a fixative that preserves and prevents changes or deterioration of the cellular components. Many of the quick stains available on the market contain the fixative in the stain.

**Staining of Blood Smears**

Stains commonly used in the examination of blood cells are described as polychromat, because they contain dyes that stain various cell components different colors. The stains usually contain methylene blue, a blue stain, and eosin, a red-orange stain. These stains are attracted to different parts of the cell, which makes the cells and their structures easier to see and differentiate. The most commonly used differential blood stain is Wright's stain. The traditional Wright's stain dyes from the early 1890s and was an alcoholic solution of methylene blue and eosin Y. The traditional stain must be diluted 1:2 with buffer before use, and this dilution generally was achieved by flooding the slide with Wright's stain, applying the buffer with a dropper, and blowing on the slide to mix. Many modifications of the original Wright's stain have been produced, most involving a chemical alteration in the methylene blue to improve polychroming. Most Wright's stains today contain mixtures of methylene blue, azure A, thionin, and eosin Y. In the quick stain, the buffer already is dissolved in the stain.

**Identification of Normal Blood Cells**

Much useful information can be gathered from microscopic identification and evaluation of blood cells in a stained smear. A great deal more information can be acquired from observation of these blood cells than from actual cell counts.

The features of blood cells that the medical assistant may observe and evaluate are cell size, nuclear appearance, and cytoplasmic characteristics. These three features allow cells to be identified, although much practice is required to be able to recognize and classify all the blood cells that may be seen in various disease states. A medical assistant might perform the differential analysis if employed in a laboratory that complies with certain CLIA regulations and if he or she is specifically trained to perform the analysis.

Cells are examined with the oil immersion objective of the microscope. The light should be bright to facilitate the visualization of colors and small structures. The slide is examined near the feathered end of the smear, where cells are barely touching one another and are easiest to identify.
RBCs are the most numerous of the cellular elements. They are biconcave disks with no nuclei. The red cells should appear pinkish tan as a result of staining of the hemoglobin in the cells (Figure 54-8).

Thrombocytes, or platelets, the smallest of the cellular elements, may be round or oval. They have no nucleus, because a platelet is just a fragment of cytoplasm from a large bone marrow cell. Platelets stain blue.

Leukocytes are the largest of the normal circulating blood cells (Table 54-4). Each of the five types has a characteristic appearance. As previously mentioned, the granulocytes include neutrophils, eosinophils, and basophils. Granulocytes have distinctive granules in the cytoplasm and may have segmented nuclei. The agranulocytes include lymphocytes and monocytes. They have few, if any, granules and nonsegmented nuclei. The nuclei of the leukocytes should appear purple, and their cytoplasm may vary from pink to blue or blue-gray. Neutrophils are known by a variety of names, including polymorphonuclear neutrophils (PMNs), segmented neutrophils, "polys," and "segs" (Figure 54-9). They are the most numerous WBCs in circulation in adults. They are produced in bone marrow, are released into the circulation, and eventually enter tissue to fight off invading microorganisms by engulfing them (phagocytosis). Many types of bacterial infections stimulate increased production of neutrophils.

<table>
<thead>
<tr>
<th>TABLE 54-4 Characteristics of Leukocytes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>GRANULOCYTES</strong></td>
</tr>
<tr>
<td><strong>NEUTROPHIL SEGMENTED (MATURE)</strong></td>
</tr>
<tr>
<td>Cell size 10-15 μL</td>
</tr>
<tr>
<td>Nucleus shape Two to five lobes</td>
</tr>
<tr>
<td>connected by threadlike filaments</td>
</tr>
<tr>
<td>Nucleus structure Coarse</td>
</tr>
<tr>
<td>Cytoplasm amount Abundant</td>
</tr>
<tr>
<td>Cytoplasm color Colorless to light pink</td>
</tr>
<tr>
<td>Cytoplasm inclusions Many tiny tan, pink, or red-purple granules</td>
</tr>
<tr>
<td><strong>NEUTROPHIL BAND (IMMATURE)</strong></td>
</tr>
<tr>
<td>Cell size 10-15 μL</td>
</tr>
<tr>
<td>Nucleus shape Band or U-shaped</td>
</tr>
<tr>
<td>Nucleus structure Coarse</td>
</tr>
<tr>
<td>Cytoplasm amount Abundant</td>
</tr>
<tr>
<td>Cytoplasm color Colorless to light pink</td>
</tr>
<tr>
<td>Cytoplasm inclusions Many tiny tan, pink with increased red-purple granules</td>
</tr>
<tr>
<td><strong>EOSINOPHIL</strong></td>
</tr>
<tr>
<td>Cell size 10-15 μL</td>
</tr>
<tr>
<td>Nucleus shape Bilobed or band</td>
</tr>
<tr>
<td>Nucleus structure Coarse</td>
</tr>
<tr>
<td>Cytoplasm amount Abundant</td>
</tr>
<tr>
<td>Cytoplasm color Colorless to light pink</td>
</tr>
<tr>
<td>Cytoplasm inclusions Many tiny tan, pink with increased red-purple granules</td>
</tr>
<tr>
<td><strong>BASOPHIL</strong></td>
</tr>
<tr>
<td>Cell size 10-15 μL</td>
</tr>
<tr>
<td>Nucleus shape Slightly segmented</td>
</tr>
<tr>
<td>granular, or band</td>
</tr>
<tr>
<td>Nucleus structure Coarse</td>
</tr>
<tr>
<td>Cytoplasm amount Abundant</td>
</tr>
<tr>
<td>Cytoplasm color Colorless to light pink</td>
</tr>
<tr>
<td>Cytoplasm inclusions Large, rounder</td>
</tr>
<tr>
<td>oval red to red-orange granule</td>
</tr>
<tr>
<td><strong>LYMPHOCYTE</strong></td>
</tr>
<tr>
<td>Cell size 6-15 μL</td>
</tr>
<tr>
<td>Nucleus shape Round or oval</td>
</tr>
<tr>
<td>Nucleus structure Obscured by granules</td>
</tr>
<tr>
<td>Cytoplasm amount Scant</td>
</tr>
<tr>
<td>Cytoplasm color Sky blue to dark blue</td>
</tr>
<tr>
<td>Cytoplasm inclusions None to few round</td>
</tr>
<tr>
<td>red-purple granules</td>
</tr>
<tr>
<td><strong>MONOCYTE</strong></td>
</tr>
<tr>
<td>Cell size 12-20 μL</td>
</tr>
<tr>
<td>Nucleus shape Round, indented, or</td>
</tr>
<tr>
<td>superimposed lobes</td>
</tr>
<tr>
<td>Nucleus structure Braintlike convolutions or folded</td>
</tr>
<tr>
<td>Cytoplasm amount Abundant</td>
</tr>
<tr>
<td>Cytoplasm color Dull gray to blue-gray</td>
</tr>
<tr>
<td>Cytoplasm inclusions Ground-glass</td>
</tr>
<tr>
<td>appearance, fine red-purple granules,</td>
</tr>
<tr>
<td>rare blue granules</td>
</tr>
</tbody>
</table>

The segmented neutrophil nucleus is segmented into two to five lobes connected by a strand. The nucleus stains a dark purple. The cytoplasm is pale pink and contains fine pink or lilac granules.

An immature form of a neutrophil is called a band or stab. Instead of having a segmented nucleus in which the lobes are separated by a thin filament, the band has an unsegmented nucleus shaped like a horseshoe or a banana. The staining is the same as in the segmented neutrophil. An increase in bands is called a shift to the left and is seen in infections such as bacterial meningitis, pneumonia, appendicitis, strep throat, and abscesses and in chronic granulocytic leukemia.

The nucleus of an eosinophil is divided into two or three lobes that stain purple. The cytoplasm stains pink and has large round or oval, red-orange granules. Eosinophils are phagocytic and are closely associated with allergies such as hay fever and with asthma, as well as with certain parasitic infestations such as tapeworm and amoebic dysentery.

The nucleus of a basophil is segmented and stains light purple. The large, dark, blue-black granules contain histamine, heparin, and other compounds that are part of the allergic response. Basophils are associated with the immediate immune response to external antigens, such as occurs with asthma, hay fever, and anaphylaxis.

Lymphocytes are the second most numerous type of WBC in adults. In children they usually are the most numerous. Their purple-staining nucleus usually is large, oval or round, and smooth. The cytoplasm stains blue. "Lymphs," as they are commonly called, are responsible for recognizing foreign antigens and producing circulating antibodies for immunity to disease. Increased numbers of lymphocytes are found with most viral diseases; with some bacterial infections, such as syphilis and tuberculosis; with leukemias; and in young children who are actively making antibodies. In many viral infections, stimulated or reactive lymphocytes, called atypical lymphocytes, are found. These are common in infectious mononucleosis.

Monocytes are the largest type of WBC in circulation. The nucleus may be oval, indented, or horseshoe shaped. The cytoplasm stains a dull gray-blue and may contain vacuoles, which appear as clear spaces in the cytoplasm filled with fluid or air. Monocytes are called macrophages when they enter tissues and ingest bacteria and debris of cellular breakdown. They are increased in patients with certain viral infections, such as hepatitis and mumps; rickettsial infections, such as Rocky Mountain spotted fever; and bacterial infections, such as tuberculosis and typhoid fever.

Differential Examination

A specific area of a stained smear must be examined microscopically when the differential count is done. This area must be where RBCs are touching but are not clumped when viewed microscopically. For manually prepared smears, this area would be the feathered edge. The entire slide is acceptable for viewing when the smear is prepared by automation. After you have located an appropriate area under low power of the microscope, focus using the oil immersion lens. The differential examination consists of counting and classifying 100 consecutive WBCs while moving in a specific winding pattern through the smear (see Figure 54-7).

FIGURE 54-10 Microscope with differential cell counter. (Courtesy Cymru, Carlinville, Ill.)

This pattern must be followed to avoid counting the same cells twice. A tally of the cells observed is kept on a differential cell counter or a computer (Figure 54-10).

Normal values for a differential vary with age. The reference ranges for adults are as follows:

- Neutrophils: 40% to 60%
- Lymphocytes: 20% to 40%
- Monocytes: 2% to 8%
- Eosinophils: 1% to 4%
- Basophils: 0.5% to 1%
- Band: 0% to 3%

Many disease states alter the ratios of the different types of leukocytes, and the differential can be very useful in assisting with the physician's diagnosis. A differential examination typically is performed in a reference laboratory.

Red Blood Cell Morphology

After the differential cell count has been determined, the RBCs are observed and evaluated. Normally, stained RBCs are the same size and shape and are well filled with hemoglobin. Any variations from the normal state are reported (Figure 54-11). The appearance of the RBCs should correlate with the RBC indices.

Size

Normal-sized RBCs are said to be normocytic. If the cells are larger than normal, they are macrocytic; if smaller, they are microcytic. The condition in which different sizes of RBCs are present is called anisocytosis.

Shape

Normal RBCs are round or slightly oval. Cells may be shaped like sickles, targets, crescents, or burrs. Poikilocytosis is a significant variation in the shape of RBCs.

Content

An RBC with a normal amount of hemoglobin is said to be normochromic. Pale-staining cells are hypochromic and have less hemoglobin than normal. Any inclusions in red cells should be reported.

Platelet Analysis

On a stained smear, the morphology of platelets is observed for any abnormalities. Platelets are small, irregularly shaped, and may
vary considerably in size. The average number of platelets seen in 10 to 15 fields is reported. The normal platelet count is 150,000 to 400,000/mm³. An increase in platelets is called thrombocytosis, and a decrease is called thrombocytopenia. Excessive clumping of platelets is reported.

In the past 10 years, the hematology laboratory has seen great advancements in the use of automation, and many procedures have become "closed tube" operations. Not only are cell counts performed by instruments that sample the tube without opening it, but slide preparation and staining can be performed by instruments that sample the specimen and make thin, consistent films or smears without ever opening the tube. These instruments are so sensitive they can adjust the film preparation based on the calculated hematocrit of the CBC. The advantages are many; closed-tube systems are safer for personnel, and results are more consistent. Still, laboratory personnel must watch closely for "flagged" or inconsistent values, and they must be prepared to perform backup tests to verify the results of the automated tests.

**ERYTHROCYTE SEDIMENTATION RATE**

The erythrocyte sedimentation rate (ESR) is a laboratory test that measures the rate at which erythrocytes gradually separate from plasma and settle to the bottom of a specially calibrated tube in an hour. The test is not specific for a particular disease but is used as a general indication of inflammation. Increases are found in such conditions as acute and chronic infections, rheumatoid arthritis, tuberculosis, hepatitis, cancer, multiple myeloma, rheumatic fever, and lupus erythematosus.

Normal values vary slightly with age and gender (Table 54-5). Only increased ESR rates are significant. Several methods of measuring the ESR are used, including the Wintrobe (Figure 54-12), Westergren (Procedure 54-4), and Landau-Adams methods. All these methods are based on the same principle and differ only in the amount of blood needed and the tube size and calibration used.

The International Committee for Standardization in Hematology has selected Westergren's method as the recommended method. A straight glass tube 30 cm long and 2.55 mm (±.015 mm) in diameter with a bore uniform to 0.05 mm throughout is used. Blood is obtained by clean venipuncture in an EDTA tube and diluted accurately with one volume of 109 mmol/L trisodium citrate to four volumes of blood. The test should be performed within 2 hours of collection, or within 6 hours if the blood is stored at 4°C (39.2°F). The diluted blood sample is drawn to the 200-mm mark in the tube by means of a mechanical device or an aspiration bulb. The tube is placed vertically in a vibration- and draft-free environment, away from direct sunlight. After 1 hour the ESR is measured in millimeters as the height of clear plasma above the column of sedimented cells.

Variations on the standard method have been developed using plastic and disposable glass tubes and capillary tubes for infants. One such method is the Sediplast (Polymedco, Redmond, Washington). This closed system incorporates a pierceable stopper that ensures a leakproof seal when pierced by a pipet. An automatic self-zeroing cap and reservoir accurately bring the blood level to the zero mark and prevent overfilling. A prefilled vial of sodium
PROCEDURE 54-4

Perform Hematology Testing: Determine the Erythrocyte Sedimentation Rate Using a Modified Westergren Method

GOAL: To fill a Westergren tube properly and to observe and record an erythrocyte sedimentation rate (ESR) obtained by using the Westergren method.

EQUIPMENT and SUPPLIES
- EDTA-anticoagulated blood specimen
- Safety tube decapper
- Sediplast ESR system
- Sediplast rack
- Timer
- Disposable gloves
- Face protector/shield
- Biohazardous waste container
- Patient's record

PROCEDURAL STEPS

1. Sanitize your hands. Put on face protection and nonsterile gloves.
   PURPOSE: To ensure infection control.

2. Assemble the materials needed.

3. Check the leveling bubble of the Sediplast rack.
   PURPOSE: The rack must be horizontal on the table or bench to ensure that the tube is vertical.

4. Bring the blood sample to room temperature if it has been refrigerated and mix the sample well by inverting the tube gently several times, making sure the tube has no bubbles.
   PURPOSE: Cells settle when a specimen stands, and blood must always be well mixed before sampling. Test results will be altered if refrigerated blood is used.

5. Remove the stopper on the blood sample using a tube decapper and on the prefilled Sediplast vial.
   PURPOSE: Removing the cap with a protective device blocks blood splashes and helps prevent aerosolization of the specimen.

6. Fill the vial to the indicated line, replace the stopper on the prefilled vial, and invert several times to mix. Recap the blood collection tube (Figure 1).
   PURPOSE: This dilutes the blood in accordance with the Westergren procedure.

7. Insert the Sediplast pipet through the pierceable stopper on the vial and push down until the pipet touches the bottom of the vial. The pipet automatically draws the blood up to the zero mark.

8. Insert the pipet and the vial into the rack, making sure the pipet is vertical (Figure 2).
   PURPOSE: A pipet that is not vertical produces erroneous results.

9. Allow the tube to stand undisturbed for 60 minutes.
   PURPOSE: Jarring increases the sedimentation rate.

10. Measure the distance the erythrocytes have fallen. The scale reads in millimeters; each line is 1 mm.

11. Clean the work area and properly dispose of all biohazard materials. Dispose of the pipet in a biohazard container. Remove your face protection and gloves and sanitize your hands.

12. Record the findings in the patient's medical record.
   REMEMBER: The Westergren ESR is reported in millimeters per hour.
   PURPOSE: A procedure is considered not done until it is recorded.

FIGURE 1

FIGURE 2 Courtesy Polymedco, Cortland Manor, N.Y.
citrate diluent is provided for dilution of blood before testing (see Procedure 54-4).

Rapid automated systems also have been developed. Strek Laboratories (La Vista, Nebraska) manufactures the ESR-10, a nonautomated, CLIA-waived test that uses ESR vacuum tubes. The tubes automatically draw the correct amount of sample and then are placed in the rack for 30 minutes. Although not CLIA-waived, analyzers that force readings are also manufactured by Strek Laboratories and allow results as quickly as 10 minutes.

Becton, Dickinson & Company (Franklin Lakes, New Jersey) has introduced the Sediview, an ESR tube that fits the Vacutainer system. This self-contained tube contains a buffered sodium citrate solution, which provides a proper dilution of blood when the tube is filled from the venipuncture. The specimen need not be transferred to another tube for analysis. The Sediview is placed in a calibrated stand from which the ESR is read after 60 minutes. The Sediview tube has a black stopper, and it should be filled with the light blue-topped and red-topped tubes, along with any other additive tubes. It should be inverted eight times after filling.

Many factors can affect the ESR. The tube must be completely filled with blood and must not have air bubbles. The tube must be allowed to sit in a vertical position, undisturbed, for a full hour. Minor degrees of tilting may increase the sedimentation rate; careful timing is important. Jarring or vibrations from nearby machinery will falsely increase the ESR. If testing cannot be performed immediately, the blood should be stored at room temperature, and testing must be performed within 62 hours.

## COAGULATION TESTING

Coagulation testing usually is performed in the hematology laboratory. The medical assistant may be asked to perform a test to determine prothrombin time (PT) using a handheld, CLIA-waived instrument that uses whole blood or citrated plasma. The PT is a method of measuring how well the blood clots. Generally, the PT is considered prolonged if it is more than 1.2 times the control time. Patients who have problems with delayed blood clotting are given a number of tests to determine the cause of the problem. The prothrombin time specifically evaluates the presence of factors VIIIa, V, and X, prothrombin, and fibrinogen. Prothrombin is a protein in the liquid part of blood (plasma) that is converted to thrombin as part of the clotting process. Fibrinogen is a type of blood protein called a globulin; it is converted to fibrin during the clotting process. With a drop in concentration of any of these factors, the blood takes longer to clot.

The PT is used in combination with the partial thromboplastin time (PTT) to screen for hemophilia and other hereditary clotting disorders. The PT also is used to monitor the condition of patients taking the drug warfarin (Coumadin). Warfarin is given to prevent clots in the deep veins of the legs and to treat pulmonary embolism. It interferes with blood clotting by lowering the liver’s production of certain clotting factors.

The ProTime Microcoagulation system (ITC, Edison, New Jersey) measures the PT based on the time it takes the blood to form a fibrin clot. A precise amount of blood is drawn from the finger stick into channels in a testing strip, where they mix with a thromboplastin reagent (Figure 54-13). The blood is pumped back and forth in the channel, and a series of light-emitting diodes (LEDs) detect the formation of the clot when the movement of the blood stops.

PT test results are reported as the number of seconds the blood takes to clot when mixed with a thromboplastin reagent. The international normalized ratio (INR) was created by the World Health Organization (WHO), because PT test results can vary, depending on the thromboplastin reagent used. The INR is a conversion unit that takes into account the different sensitivities of available reagents. It is widely accepted as the standard unit for reporting PT results rather than the time in seconds. Normal PT values are 10 to 13 seconds, or an INR of 1 to 1.4. The warfarin (Coumadin) dosage in people treated to prevent the formation of blood clots or in those with artificial heart valves usually is adjusted so that the PT is about 1.5 to 2.5 times the normal value (or INR values 2 to 3).

It is important that the medical assistant know how to accurately document INR follow up and related Coumadin dosages on a laboratory flow sheet. The physician will balance repeated INR levels with Coumadin doses so the INR is maintained at 2 throughout the anticoagulant treatment period (Figure 54-14).

## IMMUNOHEMATOLOGY

Formerly called the blood bank, the immunohematology division of the laboratory is responsible for blood typing. The major reason for performing immunohematologic tests is to prevent problems caused by incompatibility of blood types. Compatibility testing (cross-matching) is performed to prevent transfusion reactions in patients receiving blood transfusions and to identify potential Rh-incompatibility problems in expectant mothers. Rh incompatibility between an expectant mother and the unborn child may result in hemolytic disease of the newborn.

### Blood Grouping

The two major blood antigen systems are the ABO (or Landsteiner) system and the Rh system. The ABO system has four major blood groups: A, B, O, and AB. A person is either Rh
TABLE 54-6 Blood Type Distribution in the United States

<table>
<thead>
<tr>
<th>TYPE</th>
<th>CAUCASIAN</th>
<th>AFRICAN-AMERICAN</th>
<th>HISPANIC</th>
<th>ASIAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>O+</td>
<td>37%</td>
<td>47%</td>
<td>53%</td>
<td>39%</td>
</tr>
<tr>
<td>O−</td>
<td>6%</td>
<td>4%</td>
<td>4%</td>
<td>1%</td>
</tr>
<tr>
<td>A+</td>
<td>33%</td>
<td>24%</td>
<td>29%</td>
<td>27%</td>
</tr>
<tr>
<td>A−</td>
<td>7%</td>
<td>2%</td>
<td>2%</td>
<td>0.5%</td>
</tr>
<tr>
<td>B+</td>
<td>9%</td>
<td>18%</td>
<td>9%</td>
<td>25%</td>
</tr>
<tr>
<td>B−</td>
<td>2%</td>
<td>1%</td>
<td>1%</td>
<td>0.4%</td>
</tr>
<tr>
<td>AB+</td>
<td>3%</td>
<td>4%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>AB−</td>
<td>1%</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>


positive or Rh negative. Certain blood types are more common in certain countries. In China more than 99% of the population has Rh-positive blood. In the United States, about 85% of the population is Rh positive. Blood type, like eye color, is inherited. Racial and ethnic differences in blood type and composition exist as a result of inheritance and populations that have migrated and mixed over time. Different kinds of animals also have different kinds of blood. Dogs have four blood types; cats have 11; cows have about 800. Table 54-6 shows the distribution of blood types of the peoples of the United States for which data are available.

**Determination of ABO Blood Group**

Determination of the ABO blood groups is a simple test that can easily be performed (Procedure 54-5), but because of the implications of performing the test incorrectly, blood typing is not CLIA waived. The test detects the presence of A or B antigens on RBCs based on the presence or absence of agglutination with a known antiserum. When the antigen on a patient’s RBCs corresponds to the test antibody, agglutination occurs. If the corresponding antigen is not present on the cells, agglutination does not occur.

In addition to the blood antigens found on RBCs, naturally occurring antibodies are found in plasma. These antibodies appear shortly after birth, and the body never produces an antibody that can combine with its own blood antigen. Because of the blood group antibodies, blood transfusions ideally should be specific: type A blood should receive type A blood in a transfusion. In emergencies, if there is no time for the laboratory to perform a type and cross-match, type O negative (O−) blood is administered. Type O negative is referred to as the “universal donor,” because there are no circulating antibodies to the ABO antigen, nor are there Rh antigens that might sensitize an Rh-negative recipient. Table 54-7 shows the compatibility among blood types for transfusion.
CHAPTER 54  Assisting in the Analysis of Blood

PROVIDE 54-5

Perform Hematology Testing: Determine the ABO Group Using a Slide Test

GOAL: To determine a patient’s ABO group accurately using the slide test technique.

EQUIPMENT and SUPPLIES

- Glass slides with frosted ends
- Anti-A and anti-B serum (Figure 1)
- Applicator sticks
- Lancet and automatic finger puncture device
- Alcohol preps
- Sterile gauze squares
- Adhesive bandage strip
- Laboratory marking pen or pencil
- Disposable gloves
- Face protector/shield
- Biohazardous waste container and sharps container
- Patient’s record

PROCEDURAL STEPS

1. Assemble all of the supplies and equipment needed to complete the testing procedure.
2. Sanitize your hands and put on face protection and gloves.
   PURPOSE: To ensure infection control.
3. Explain the procedure to the patient.
   PURPOSE: Explaining the reason for a diagnostic procedure helps gain the patient’s compliance and addresses the person’s questions and concerns.
4. Label the slides in the frosted area with the patient’s name.
   PURPOSE: To ensure proper identification of test results.
5. Place one drop of anti-A serum on slide 1, one drop of anti-B serum on slide 2, and one drop of anti-A and anti-B serum on slide 3.
6. Select the puncture site, cleanse the site with an alcohol pad, and perform a finger puncture.
7. Wipe away the first drop of blood.
   PURPOSE: The first drop of blood may contain tissue fluid.
8. Place one large drop of blood on each of the three prepared slides, close to but not touching the drop of antiserum.
9. Cover the puncture site with a sterile gauze square, and instruct the patient to apply gentle pressure to the site.
10. Mix the antiserum and blood thoroughly, using a clean applicator stick for each slide. Rock the slide after mixing to check for agglutination. The mixture should be spread over an area measuring approximately 20 x 40 mm.
11. Read and interpret the results of the reaction for all slides (Figure 2).
12. Make sure the patient has stopped bleeding and apply a bandage strip to the puncture site if necessary.
13. Discard all biohazard testing waste in the appropriate container.
   PURPOSE: To ensure infection control.
14. Clean the testing area and sanitize your hands.
15. Record the testing results in the patient’s record.
   PURPOSE: A procedure is not considered done until it is recorded.
NOTE: Because of the serious implications of incorrect blood typing, ABO and Rh typing are not routinely performed in a physician’s office laboratory. Instead, these tests are performed in a hospital or blood bank.

Determination of Rh Factor

Determination of the Rh type also is a simple test (although it is not CLIA waived) that can be performed with a minimum amount of equipment (Procedure 54-6). The Rh factor is so-called because it was first discovered in rhesus monkeys. Later, this same protein was found on the RBCs of some humans. This test detects the presence of proteins (D antigens) on the surface of RBCs based on the presence or absence of agglutination with anti-D antiserum. When the D antigen is present, agglutination occurs when the anti-D antiserum is mixed with RBCs. If the D antigen is not present, agglutination does not occur. Rh-positive blood agglutinates in the presence of anti-D antiserum but not in the presence of the Rh control. Rh-negative blood does not agglutinate in the presence of anti-D antiserum, nor does it agglutinate in the presence of the Rh control.
PROCEEDURE 54-6

Perform Hematology Testing: Determine the Rh Factor Using the Slide Method

GOAL: To determine accurately the presence or absence of anti-D agglutinations.

EQUIPMENT and SUPPLIES

- Two glass slides with frosted ends
- Anti-D serum (Figure 1)
- Applicator sticks
- Lancet and automatic finger puncture device
- Alcohol prep
- Sterile gauze squares
- Laboratory marker or pencil
- Disposable gloves
- Face protector/shield
- Biohazardous waste container
- Patient’s record

PROCEDURAL STEPS

1. Assemble all the equipment and supplies needed to perform the test.
2. Sanitize your hands and put on face protection and gloves.
   PURPOSE: To ensure infection control.
3. Label one slide “D” and one slide “C.”
   PURPOSE: To differentiate between the anti-D slide and the control slide.
4. Place one drop of anti-D serum on the D slide.
5. Place one drop of the appropriate control reagent on the C slide.
6. Perform a capillary puncture to secure a blood specimen.
7. To each slide, add one large drop of the patient’s blood, close to but not touching the antiserum.
8. Thoroughly mix the blood with the anti-D serum and the control, using a clean applicator stick for each slide, and spread the reaction mixture over an area measuring approximately 20 x 40 mm on each slide.
9. Place the slide on an Rh view box.
   PURPOSE: The view box provides warmth, which promotes agglutination, and also provides extra illumination for viewing.
10. Read the results immediately.
    PURPOSE: Drying of the reaction mixture must not be confused with agglutination.
11. Discard all disposable equipment in the proper biohazardous waste containers.
12. Clean the area. Remove your gloves and face protection and sanitize your hands.
    PURPOSE: To prevent infection control.
13. Record the test results.
    PURPOSE: A procedure is not considered done until it is recorded.
    NOTE: Because of the serious implications of incorrect blood typing, ABO and Rh typing are not routinely performed in a physician’s office laboratory. Instead, these tests are performed in a hospital or blood banking facility.

BLOOD AGGLUTINATION PRINCIPLES

- Type A blood agglutinates in the presence of anti-A antiserum but does not agglutinate in the presence of anti-B antiserum.
- Type B blood agglutinates in the presence of anti-B antiserum but not in the presence of anti-A antiserum.
- Type O blood does not agglutinate in the presence of either anti-A antiserum or anti-B antiserum.
- Type AB blood agglutinates in the presence of both anti-A antiserum and anti-B antiserum.

There are no naturally occurring antibodies to the Rh factor as there are to the A and B antigens. A person develops antibodies to the D antigen only in the event of exposure to the antigen. This is possible if an incompatible transfusion is administered or if an Rh-negative mother is exposed to the Rh-positive blood of her infant during pregnancy, miscarriage, abortion, or delivery. If this occurs, the mother may develop antibodies to the D antigen. This usually does not cause a problem during the first pregnancy. However, in subsequent pregnancies with an Rh-positive fetus, the woman’s immune system begins to produce more antibodies, because she was sensitized during the first pregnancy. These antibodies cross the placenta and destroy the RBCs of the fetus, which can lead to anemia, heart failure, or brain damage in the infant and may even cause death. These events are collectively called hemolytic disease of the newborn (HDN). The disease sometimes is also called hydrops or blue baby syndrome. Until 1968, no preventive measure could be taken for this problem. Exchange transfusion, in which all the infant’s blood is replaced, was the only option. Today, however, HDN can be prevented by the admini-
TABLE 54-8 Other Blood Typing Systems

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diego</td>
<td>Found only among East Asians and Native Americans.</td>
</tr>
<tr>
<td>MNS</td>
<td>Useful in maternity and paternity testing.</td>
</tr>
<tr>
<td>Duffy</td>
<td>The malaria parasite requires the Duffy antigen to enter the red blood cells. Lack of the antigen confers resistance to malaria. Duffy-negative blood is found only in descendants of African populations.</td>
</tr>
<tr>
<td>Lewis</td>
<td>Antigens are soluble in blood rather than attached to the red blood cells. These are the only blood group antibodies that have never been implicated in hemolytic disease of the newborn.</td>
</tr>
</tbody>
</table>

Other blood group systems include Colton, M, Kell, Kidd, Lewis, Landsteiner-Wiener, P, Yt or Carnwath, Xc, Sicelione, Dombrock, Clonidine/Roggers, Kc, Gpi-Ic, Cranmer, Knox, Indian, Ok, Rupl, and JMH.

These blood type systems generally are not significant for blood donations but can be troublesome for individuals who have had numerous transfusions and may have developed atypical antibodies, making future cross-matching more of a challenge. The American Red Cross, in collaboration with the American Association of Blood Banks (AABB), maintains a rare donor database as part of the American Rare Donor Program. When a rare blood type is needed, those in the registry can be contacted to make a donation. In addition, blood of a rare type can be frozen to ensure availability when needed.

CRITICAL THINKING APPLICATION 54-4

Before Mr. Corrigan's kidney transplant, he had a type O and cross-match and was determined to be type O+. Explain how the test was performed and what the technician observed with the anti-A, anti-B, and anti-D antisera.

CLINICAL CHEMISTRY

Most clinical chemistry methods are classified as moderately complex according to CLIA guidelines, and only people with documented training in the method are permitted to perform testing, which must be done under the supervision of the director of the physician's office laboratory. Increasingly, however, clinical chemistry tests are being granted CLIA-waived status.

BLOOD GLUCOSE TESTING

Glucose is used as a fuel by many body cells; under normal circumstances, it is the only substance used to nourish brain cells. Maintenance of blood glucose levels within a normal range is vital to homeostasis of the human body. Understanding the importance of glucose can help the medical assistant understand why glucose is the most frequently tested analyte.

Elevated blood glucose levels most often are associated with diabetes mellitus, but they also may indicate pancreatitis, endocrine disorders, or chronic renal failure. Diabetes mellitus is a disorder of carbohydrate metabolism that results in elevated blood and urine glucose levels secondary to the pancreas' inability to produce sufficient insulin. (Diabetes is discussed in Chapter 45.)

To check a patient for diabetes mellitus, the physician may request a blood glucose tolerance test (GTT). For this test the fasting patient receives an adequate carbohydrate meal of 100 g of glucose by mouth. This usually is given to the patient as a drink that is similar to a sweet fruit punch. The amount may be adjusted according to the patient's weight. If the glucose level does not exceed 100 g/dL at the onset of the testing period, or 180 g/dL 1 hour after ingestion of the glucose drink, the patient is believed to have a normal glucose level. If the blood glucose level exceeds 200 g/dL, glucose escapes into the urine, because the renal tubules no longer are able to absorb the excessive amount present in the glomerulus.

Self-monitoring of blood glucose levels has become an important part of the treatment of diabetes. Testing methodologies have evolved over the past 20 years. The earliest test methods available were urine reagent strips (see Chapter 52) that detected glucose...
and ketones. Although simple to use, they lacked the precision to be useful for adjusting insulin dosage. In the 1970s similar strips for testing glucose levels in the blood were introduced. A drop of blood from a capillary puncture was applied to the strip, and the excess was wiped away. After careful timing, the color of the pad on the reagent strip was compared with a chart. The results were highly dependent on the user.

The first handheld devices were marketed shortly after this and were designed to test the test strips electronically rather than visually using reflectance photometry. Although this technology still required wiping and timing, the devices were precise enough to monitor blood glucose and assist with insulin adjustment.

In the 1980s, blood glucose monitors using electrochemistry and devices that used reflectance photometry joined the market. The need for wiping and timing was eliminated. These technologies use an enzyme to convert glucose to measurable products. Enzymes commonly used are glucose oxidase, glucose dehydrogenase, and hexokinase.

The medical assistant can screen a patient’s blood glucose levels by using a glucometer cleared for home use by the U. S. Food and Drug Administration (FDA). (This procedure was described in Chapter 45; see Procedure 45-1.) The blood glucose level is routinely monitored by patients with diabetes mellitus type 1 or type 2. Glucose levels also may be monitored by women with gestational diabetes, a condition seen during pregnancy in which the effect of insulin is partially blocked by a variety of other hormones made in the placenta.

## Hemoglobin A₁c Testing

During the past two decades, diabetes researchers have developed several new laboratory tests that aid the evaluation of blood glucose levels. These tests measure glycohemoglobin, fructosamine, and glycated protein. These tests are not substitutes for monitoring of blood glucose levels; rather, they give different information about the health of the patient with diabetes and add a new dimension to the evaluation of the disease.

The glycohemoglobin test was developed in the late 1970s. Other names that have been used to describe the same test are glycosylated hemoglobin and hemoglobin A₁c. This test gives information about the average blood sugar level during the past 2 or 3 months. In the blood, glucose binds irreversibly to hemoglobin molecules in RBCs. The amount of glucose that is bound to hemoglobin is directly tied to the concentration of glucose in the blood.

Because RBCs have a life span of approximately 120 days, measuring the amount of glucose bound to hemoglobin can provide an assessment of average blood sugar control during the 60 to 90 days preceding the test. This is the purpose of the glycohemoglobin tests, most commonly the hemoglobin A₁c (HbA₁c) measurement. Because the test results give feedback on the previous 2 to 3 months, an HbA₁c test every 3 months provides data on the average blood glucose level. If the glycohemoglobin value is higher than the normal range, the average blood sugar has been elevated during the past 2 months. The normal HbA₁c level for a person without diabetes ranges from 4% to 6%. For patients with diabetes, the goal is to maintain the glycosylated hemoglobin level below 7%. Table 54-9 associates glycosylated hemoglobin levels with blood glucose levels. If the HbA₁c levels are 9% or higher, the patient’s treatment should be reassessed, or the physician may question the patient’s compliance with treatment. HbA₁c levels of 7% to 8% are considered good, and those below 7% demonstrate excellent blood glucose control.

Several methods can be used to measure the HbA₁c, and the medical assistant can perform HbA₁c testing using several CLIA-waived devices. The DCA 2000, made by Bayer Diagnostics (Tarrytown, New York), provides HbA₁c values in 6 minutes from one drop of capillary blood obtained from a finger stick. Patients also can perform HbA₁c testing at home using FDA-approved instrumentation, including the A1CNow by Metrika (Sunnyvale, California) and the Micromat II from Bio-Rad (Hercules, California).

The fructosamine test was developed more recently. Fructosamine is a term that refers to the linking of blood sugar onto protein molecules in the bloodstream. Fructosamine levels change more rapidly than glycohemoglobin levels. The fructosamine value depends on the average blood sugar level during the past 3 weeks; therefore, this test might be able to detect changes in diabetic control earlier than the glycohemoglobin test. The fructosamine test could be viewed as complementary to the glycohemoglobin test, because the two tests are different reflections of diabetes control: the glycohemoglobin test looks back approximately 8 weeks, and the fructosamine test looks back approximately 3 weeks.

Other tests similar to the fructosamine test have been proposed, such as the glycosylated protein test. Unfortunately, these newer tests are less reliable than originally hoped, and it seems unlikely that either the fructosamine test or the glycosylated protein test will ever become as widely used for monitoring diabetes as the glycohemoglobin level test.

### CRITICAL THINKING APPLICATION 54-5

Mr. Corrigan routinely monitors his blood sugar. Why is Dr. Fischbach also interested in his hemoglobin A₁c levels? What complications of diabetes led to Mr. Corrigan’s need for a transplant?
CHAPTER 54   Assisting in the Analysis of Blood

**CHOLESTEROL TESTING**

Cholesterol is a fatlike substance (lipid) present in cell membranes. It also is needed to form bile acids and steroid hormones. Cholesterol travels in the blood in distinct particles containing both lipid and proteins. These particles are called lipoproteins. The cholesterol level in the blood is determined partly by inheritance and partly by acquired factors, such as diet, calorie balance, and level of physical activity.

Patients often are confused by cholesterol testing. The confusion is caused partly by the way some people use the term cholesterol, which often is a catchall term for both the cholesterol a person eats and the cholesterol that is maintained in the body. A high level of low-density lipoprotein, or LDL cholesterol, reflects an increased risk of heart disease, which is why LDL cholesterol often is called “bad” cholesterol. Lower levels of LDL cholesterol reflect a lower risk of heart disease. When too much LDL cholesterol circulates in the blood, it can slowly build up in the walls of arteries that feed the heart and brain. Together with other substances, it can form plaque, a thick, hard deposit that can clog those arteries. This condition is known as atherosclerosis. If a clot (thrombus) forms at the site of plaque, blood flow can be blocked to part of the heart muscle, causing a heart attack. If a clot blocks blood flow to part of the brain, a stroke results.

About one third to one fourth of blood cholesterol is carried by high-density lipoprotein (HDL). HDL cholesterol is known as the “good” cholesterol, because a high level of HDL cholesterol seems to protect against heart attack. Medical experts think that HDL tends to carry cholesterol away from the arteries and back to the liver, where it is passed from the body. Some experts believe that excess cholesterol is removed from atherosclerotic plaque by HDL, which slows the buildup; however, low HDL cholesterol levels (i.e., lower than 35 mg/dL) may result in a greater risk of heart disease.

Adults over age 20 should have a cholesterol test at least once every 5 years. Total cholesterol, the combination of HDL and LDL, typically is measured (Procedure 54-7); however, the physician may order an HDL determination separately. Both tests are considered screening tests, and elevated results always require additional testing before a diagnosis can be made. In general, total cholesterol levels under 200 mg/dL are considered normal. Results over 240 mg/dL are considered elevated and, based on confirmed testing, place a person in the high-risk category for coronary heart disease. An HDL cholesterol level of 35 mg/dL is considered acceptable. Values below 35 mg/dL place a person in the high-risk category.

Although the total cholesterol and HDL cholesterol levels are not significantly affected by food consumption, you should follow office policy for patient education in preparation for the test. Most physicians prefer that patients fast for 12 hours before cholesterol levels are checked. If the total cholesterol is elevated, the physician is likely to order a lipid profile, which is a series of tests that measures the total cholesterol, triglyceride, and HDL and LDL cholesterol levels. Triglyceride levels are affected by food consumption, and the patient must be instructed to fast before the test.

CLIA-waived cholesterol monitors can measure HDL cholesterol, total cholesterol, and triglycerides. The Cholestech LDX analyzer (Cholestech, Hayward, California), uses enzymatic reactions to produce products that are quantified by reflectance photometry using blood from a finger stick.

**Thyroid Hormone Testing**

The thyroid gland is located anterior to the trachea in the throat. It produces the hormones triiodothyronine (T3) and thyroxine (T4). These hormones are essential for life and have many effects on body metabolism, growth, and development. The thyroid gland is influenced by hormones produced by two other organs found in the brain, the pituitary gland and the hypothalamus. The pituitary gland produces thyroid-stimulating hormone (TSH), and the hypothalamus produces thyrotropin-releasing hormone (TRH). (Regulation of thyroid hormone production and thyroid disorders are discussed in Chapter 45.)

CLIA-waived rapid diagnostic tests to qualitatively measure TSH are available for point of care testing. Using whole blood from a finger stick, these tests screen patients for hypothyroidism by detecting elevated levels of TSH, which constitutes a sign of hypothyroidism. The tests use lateral flow chromatographic immunoassay technology housed in a plastic cassette similar to the pregnancy test discussed in Chapter 52. One such commercially available test is the ThyroTest (ThyroTek, Honeybrook, Pennsylvania).

**Alanine Aminotransferase and Aspartate Aminotransferase Testing**

Certain drugs can impair liver function and require monitoring of liver enzymes. These drugs include statins and fibrates, pharmaceutical agents used to lower blood cholesterol, and certain antidiabetic and antihypertensive drugs. Liver function also must be monitored during therapy with drugs that have the potential to cause liver malfunction. Two liver enzymes, aspartate aminotransferase (AST) and alanine aminotransferase (ALT), can be useful for monitoring homoeostasis during drug therapy. The first liver enzyme testing to be CLIA waived was the Cholestech ALT/AST test, which is performed on the Cholestech LDX System (Cholestech). This system also analyzes glucose, total cholesterol, HDL, and triglycerides using a combination of enzymatic reactions and reflectance photometry to detect the resulting color changes.

**CRITICAL THINKING APPLICATION 54-6**

For what reason might Dr. Fischbech want to evaluate Mrs. Corrigan’s liver enzymes? What clinical chemistry tests might he order from the referral laboratory? What Vacutainer tube would be needed for these tests? What tests for liver enzymes might Dana be able to perform in the physician’s office laboratory? What sample will she need for those tests?

**Chemistry Panels**

Automated blood chemistry analyzers are often used to perform blood chemistry testing. It is not uncommon for several analytes to be detected at once. A physician may order a chemistry panel, such as a renal or liver panel, that determines the levels of several related analytes (Figure 54-15). Analytes commonly detected in the chemistry laboratory are listed in Table 54-10. Generally, serum is needed for these tests. Typical panels are shown in Table 54-11.
Perform Chemistry Testing: Determine Cholesterol Level Using a ProAct Testing Device

**GOAL:** To perform a ProAct test for total cholesterol level and accurately report the results.

**ORDER:** Perform a total blood cholesterol level on Connie Lange stat.

**EQUIPMENT and SUPPLIES**

- ProAct testing device
- Sterile gauze
- Lithium heparin
- Alcohol prep
- Capillary tube and capillary pipet
- Lancets and lancet device
- Disposable gloves
- Biohazardous waste container and sharps container
- Patient’s record

**PROCEDURAL STEPS**

1. Reread the physician’s order and assemble all the supplies and equipment needed to complete the test.
2. Sanitize your hands and put on gloves.
   **PURPOSE:** To ensure infection control.
3. Explain the procedure to the patient.
4. Load the lancet device with a sterile lancet.
5. Examine the patient’s index and ring fingers and pick a puncture site.
   **PURPOSE:** The puncture site must be free of trauma.
6. Clean the chosen puncture site with alcohol and allow the site to air dry.
7. Puncture the site and wipe away the first drop of blood with a sterile gauze square.
   **PURPOSE:** The first drop of blood may contain tissue fluid.
8. Hold the capillary tube horizontally by the colored end of the tube and allow the tube to fill. Do not allow air bubbles to enter the tube; if this occurs, discard the capillary tube and continue drawing the sample with a new tube.
   **PURPOSE:** Air bubbles may cause erroneous test results.
9. Give the patient a clean gauze square and ask the person to apply pressure to the puncture site.
10. Remove a cholesterol testing strip from the container and close the container immediately (Figure 1).
    **PURPOSE:** Closing the container prevents possible exposure of the unused strips.
11. Remove the foil protecting the test area of the strip and place the strip on a dry, hard, flat surface (Figure 2).
12. Attach the capillary tube filled with blood to the pipet.
13. Squeeze the plunger of the pipet completely to allow a drop of blood to form at the end of the capillary tube.
14. Allow the drop of blood to fall onto the center of the red mesh application zone. Make sure the tip of the capillary tube does not touch the test strip and that all blood is dispensed (Figure 3).
   **PURPOSE:** To obtain the best test results, the strip must be saturated with blood.
15. Allow the sample to soak into the red mesh for 3 to 15 seconds.
16. Insert the cholesterol strip into the test port. The ProAct device counts down approximately 160 seconds (Figure 4).
17. Remove the capillary tube from the pipet and discard it in a biohazardous waste container.
   **PURPOSE:** To ensure infection control.
18. When the measurement time is complete, REMOVE STRIP appears in the LED display window. Remove the used test strip; the test result will appear on the display (Figure 5).

---

**FIGURE 1** From Singo CA, Woods MA. Laboratory procedures for medical office personnel, Philadelphia, 1998, Saunders.

**FIGURE 2**

**FIGURE 3**

**FIGURE 4**
### PROCEDURE 54-7—cont’d

19. Examine the test area of the used testing strip for uneven color development before discarding it in the biohazardous waste container.
   **PURPOSE:** If the color appears mottled, the test may not be valid, and it is advisable to repeat the entire test process.

20. Discard all biohazardous waste in the appropriate containers, clean the test area, remove your gloves, and sanitize your hands.
   **PURPOSE:** To ensure infection control.

21. Record the test results in the patient’s medical record.
   **PURPOSE:** A procedure is not considered done until it is recorded.

---

#### TABLE 54-10 Blood Chemistry Tests

<table>
<thead>
<tr>
<th>TEST</th>
<th>ABBREVIATION</th>
<th>NORMAL VALUES</th>
<th>DESCRIPTION</th>
<th>PURPOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanine aminotransferase</td>
<td>ALT (SGPT)</td>
<td>&lt;45 U/L</td>
<td>Enzyme found predominately in the liver but also in the kidney</td>
<td>To detect liver disease</td>
</tr>
<tr>
<td>Albumin</td>
<td></td>
<td>3.5-5 g/dl</td>
<td>Protein</td>
<td>To assess kidney function</td>
</tr>
<tr>
<td>Alkaline phosphatase</td>
<td>ALP</td>
<td>20-70 U/L</td>
<td>Enzyme found in several tissues</td>
<td>To detect liver and bone disease</td>
</tr>
<tr>
<td>Aspartate aminotransferase</td>
<td>AST (SGOT)</td>
<td>&lt;40 U/L</td>
<td>Enzyme found in several tissues</td>
<td>To detect tissue damage</td>
</tr>
<tr>
<td>Blood urea nitrogen</td>
<td>BUN</td>
<td>7.1-18 mg/dL; 2.5-6.4 mmol/L</td>
<td>Metabolic products of protein catabolism</td>
<td>To detect renal disease</td>
</tr>
<tr>
<td>Calcium</td>
<td>CA</td>
<td>8.4-10.2 mg/dL; 2.1-2.6 mmol/L</td>
<td>Mineral</td>
<td>To assess parathyroid function and calcium metabolism</td>
</tr>
<tr>
<td>Chloride</td>
<td>Cl</td>
<td>98-106 mmol/L</td>
<td>Electrolyte</td>
<td>To determine acid-base and water balance</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>CH, Chol</td>
<td>Total: &lt;200 mg/dL; &lt;5.18 mmol/L LDL: &lt;130 mg/dL; &lt;3.37 mmol/L HDL: &gt;35 mg/dL; &gt;0.91 mmol/L</td>
<td>Lipid</td>
<td>Screening for atherosclerosis related to heart disease</td>
</tr>
<tr>
<td>Creatine phosphokinase</td>
<td>CPK</td>
<td>Specific to testing method used</td>
<td>Enzyme found in several tissues</td>
<td>To assess source of muscle damage (myocardial infarct)</td>
</tr>
<tr>
<td>Creatinine</td>
<td>creat</td>
<td>0.2-0.8 mg/dL</td>
<td>Metabolic product of protein catabolism</td>
<td>To screen for renal function</td>
</tr>
<tr>
<td>Ferritin</td>
<td></td>
<td>20-50 ng/mL</td>
<td>Iron-carrying protein</td>
<td>To detect amount of iron stored in the body</td>
</tr>
<tr>
<td>Gamma glutamyltransferase</td>
<td>GGT</td>
<td>0-45 U/L</td>
<td>Enzyme found mainly in liver cells</td>
<td>To detect liver disease</td>
</tr>
<tr>
<td>Globulin</td>
<td>glob, lg</td>
<td>Varies according to type</td>
<td>Protein</td>
<td>To detect abnormalities in protein synthesis and removal</td>
</tr>
<tr>
<td>Glucose fasting blood sugar</td>
<td>FBS</td>
<td>70-100 mg/dL; 3.9-6.1 mmol/L</td>
<td>Carbohydrate</td>
<td>To detect disorders of glucose metabolism (diabetes)</td>
</tr>
<tr>
<td>Glucose tolerance test</td>
<td>GTT</td>
<td>Varies with time</td>
<td>Carbohydrate</td>
<td>To detect disorders of glucose metabolism (diabetes)</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>35-140 mcg/dL</td>
<td>Mineral</td>
<td>To assist in diagnosis of anemia</td>
</tr>
<tr>
<td>Lactate dehydrogenase</td>
<td>LDH</td>
<td>&lt;240 U/L</td>
<td>Enzyme found in several tissues</td>
<td>To assist in confirmation of myocardial or pulmonary infarct</td>
</tr>
</tbody>
</table>

---

5/25/XX 9:30 AM Total cholesterol test performed as ordered. ProAct test results 247.
D. Cummings, CMA (AAMA)
### TABLE 54-10 Blood Chemistry Tests—cont’d

<table>
<thead>
<tr>
<th>TEST</th>
<th>ABBREVIATION</th>
<th>NORMAL VALUES</th>
<th>DESCRIPTION</th>
<th>PURPOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>pH</td>
<td>7.35-7.45</td>
<td></td>
<td>To assess acidity or alkalinity of blood</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
<td>3.4-5.1 mg/dl; 0.97-1.45 mmol/L</td>
<td>Mineral</td>
<td>To assist in proper evaluation of calcium levels and to detect endocrine system disorders</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
<td>3.5-5.3 mmol/L</td>
<td>Mineral</td>
<td>To assist in diagnosis of acid-base and water balance</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>135-146 mmol/L</td>
<td>Mineral</td>
<td>To assist in diagnosis of acid-base and water balance</td>
</tr>
<tr>
<td>Total bilirubin</td>
<td>TB</td>
<td>0.2-1 mg/dl; 3.4-17.1 mmol/L</td>
<td>Metabolic product of hemoglobin catabolism</td>
<td>To evaluate liver function and to aid in diagnosis of anemia</td>
</tr>
<tr>
<td>Total iron-binding capacity</td>
<td>TIBC</td>
<td>245-400 μg/dl</td>
<td></td>
<td>A measure of the potential to transport iron</td>
</tr>
<tr>
<td>Total protein</td>
<td>TP</td>
<td>6-8 g/dl; 60-80 g/L</td>
<td></td>
<td>To assess the state of hydration; to screen for diseases that alter protein balance</td>
</tr>
<tr>
<td>Troponin I and T</td>
<td></td>
<td>&lt;0.4</td>
<td>Cardiac-specific protein found only with heart muscle damage</td>
<td>To aid in diagnosis of myocardial infarct</td>
</tr>
<tr>
<td>Thyroid-stimulating hormone (thyrotropin)</td>
<td>TSH</td>
<td>5-6 mU/L</td>
<td>Hormone produced by the pituitary</td>
<td>To assess thyroid and pituitary gland function</td>
</tr>
<tr>
<td>Thyroxine</td>
<td>T₄</td>
<td>5-12 mcg/dl; 64-155 mmol/L</td>
<td>Hormone produced by the thyroid gland</td>
<td>To assess thyroid function</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>Trig</td>
<td>30-190 mg/dl; 0.34-2.15 mmol/L</td>
<td></td>
<td>Screening for atherosclerosis related to heart disease</td>
</tr>
<tr>
<td>Triiodothyronine</td>
<td>T₃</td>
<td>27%-47%</td>
<td>Hormone produced by the thyroid gland</td>
<td>To assess thyroid function</td>
</tr>
<tr>
<td>Uric acid</td>
<td>UA</td>
<td>Male: 3.4-7 mg/dl; 202-416 μmol/L; Female: 2.4-6 mg/dl; 143-357 μmol/L</td>
<td>Metabolic product of protein catabolism</td>
<td>To evaluate renal failure, gout, and leukemia</td>
</tr>
</tbody>
</table>

### TABLE 54-11 Typical Chemistry Panels

<table>
<thead>
<tr>
<th>PANEL</th>
<th>COMPONENT</th>
<th>PANEL</th>
<th>COMPONENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liver</td>
<td>Alkaline phosphatase (ALP)</td>
<td>Cardiac</td>
<td>Creatinine phosphokinase (CPK)</td>
</tr>
<tr>
<td></td>
<td>Gamma glutamyltransferase (GGT)</td>
<td></td>
<td>Troponin I</td>
</tr>
<tr>
<td></td>
<td>Aspartate aminotransferase (AST)</td>
<td></td>
<td>Troponin T</td>
</tr>
<tr>
<td></td>
<td>Alanine aminotransferase (ALT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lactate dehydrogenase (LDH)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anemia</td>
<td>Iron</td>
<td>Electrolyte</td>
<td>Sodium</td>
</tr>
<tr>
<td></td>
<td>Total iron-binding capacity</td>
<td></td>
<td>Potassium</td>
</tr>
<tr>
<td></td>
<td>Ferritin</td>
<td></td>
<td>Chloride</td>
</tr>
<tr>
<td></td>
<td>Transferrin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thyroid</td>
<td>Thyroid-stimulating hormone (TSH)</td>
<td>Renal</td>
<td>Creatinine</td>
</tr>
<tr>
<td></td>
<td>Thyroxine (T₄)</td>
<td></td>
<td>Blood urea nitrogen</td>
</tr>
<tr>
<td></td>
<td>Triiodothyronine (T₃)</td>
<td></td>
<td>Uric acid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Glucose</td>
</tr>
</tbody>
</table>
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77352 E. CAPITAL DRIVE
ANYTOWN, USA 11123

**FIGURE 54-15** Panel request form. (From Stepp CA, Woods MA: Laboratory procedures for medical office personnel, Philadelphia, 1998, Saunders.)

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**CRITICAL THINKING APPLICATION 54-7**

What tests are routinely done as part of the renal panel? What information will these tests give Dr. Fischbach about the status of Mr. Corrigan's kidney?

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**CLOSING COMMENTS**

**Legal and Ethical Issues**

In 1991 many states adopted the Blood Safety Act, which requires physicians to provide patients with information about blood transfusion options. This information is given before surgery and...
before any medical procedure in which the possibility exists that blood transfusion may be necessary. Physicians also are required to note on each patient's medical record that a written summary was given to the patient. As the physician's agent, you share this responsibility. If this is needed for a particular patient, every member of the healthcare team is responsible for ensuring that (1) the patient is provided with the information; (2) this is noted on the patient's chart and initialled; and (3) the written summary is formally prepared (copies of the official form can be requested from the state department of health services).

**SUMMARY OF SCENARIO**

Dana knows the important role laboratory analysis of blood plays in patient care. Often many different tests are needed to assess a patient's health. Mr. Corrigan appreciates that he can have many of these tests done during his routine visits with a simple finger stick, such as the hemoglobin A1c level, hemoglobin and hematocrit, PT, and ALT/AST testing. The anemia panel, CBC and differential, and hemoglobin and hematocrit provide Dr. Fischbach with essential information for diagnosing anemia, and the hemoglobin A1c level is used to monitor Mr. Corrigan's diabetes. The prothrombin time, which monitors coagulation, and the liver enzyme tests assure Dr. Fischbach that Mr. Corrigan's liver is functioning properly while he is taking medication to treat his diabetes and to manage the transplant.

**SUMMARY OF LEARNING OBJECTIVES**

1. Define, spell, and pronounce the terms listed in the vocabulary. Spelling and pronouncing medical terms correctly bolster the medical assistant's credibility. Knowing the definitions of these terms promotes confidence in communication with patients and co-workers.

2. Apply critical thinking skills in performing the patient assessment and patient care. Completing the Critical Thinking Application exercises throughout the chapter can help the student medical assistant become more adept at critical analysis of real-life situations.

3. Name three main functions of blood. Blood supplies cells with needed nutrients, delivers oxygen to tissues through hemoglobin, and removes waste.

4. Identify the role of the hematology laboratory in patient care. In the hematology laboratory, blood cells are enumerated, WBCs are differentiated, and the oxygen-carrying capacity of blood is determined. Hematology testing provides an excellent overview of homeostasis.

5. Describe the appearance and function of erythrocytes. Erythrocytes are also called red blood cells because of their red color, which comes from hemoglobin. The biconcave discs lack a nucleus and are responsible for transporting oxygen and carbon dioxide to and from tissues.

6. Describe the appearance and function of granular and agranular leukocytes. Leukocytes are also called white blood cells. Agranular leukocytes lack granules in the cytoplasm, and granular leukocytes have granules. All leukocytes function in fighting infection.

7. Differentiate between T cells and B cells. T lymphocytes are important in immunity and play roles in killing foreign, virus-infected, and tumor cells; they also assist in antibody production and keep the immune system in check. B cells are responsible for antibody production.

8. Describe the appearance and function of thrombocytes. A thrombocyte (platelet) is a fragment of a larger cell (megakaryocyte) found in the bone marrow. Thrombocytes play an important role in clot formation, both physically and chemically.

9. Explain the process of clot formation. Clot formation begins with the aggregation of thrombocytes, which release a substance that initiates the clotting cascade, resulting in a network of minute threads that trap plasma and blood cells.

10. Identify the anticoagulant of choice for hematology testing. The anticoagulant required for most hematology testing is ethylenediamine tetraacetic acid (EDTA). The lavender-topped vacuum tube used in phlebotomy contains this anticoagulant.

11. Explain the purpose of a microhematocrit test. A microhematocrit (or hematocrit) test is performed to assess the volume of erythrocytes in relationship to total blood volume by centrifuging a small amount of whole blood in a capillary tube. Whole blood normally consists of slightly less than 50% RBCs. Hematocrit is reported as a percentage and is roughly three times that of hemoglobin.

12. Perform a microhematocrit test. Refer to Procedure 54-1.

13. Explain the role of hemoglobin in the body. Hemoglobin is the RBC protein responsible for oxygen transport from the lungs to the tissues. It gives the blood its red color.


15. Identify the tests included in a complete blood count (CBC) and their reference ranges. The CBC involves an erythrocyte count, a leukocyte count, a thrombocyte count, a hemoglobin and hematocrit determination, a differential examination of leukocytes, and calculation of red cell indices.

16. Explain the process of automated blood cell counting. Blood first is diluted in a fluid that conducts an electrical current. The diluted sample passes through a narrow opening in the blood counting instrument, interrupting the flow of electrical current, and each interruption is counted.

17. Distinguish between normal and abnormal test results. Refer to the hematology diagnostic reference ranges in Table 54-3 and Figure 54-6.
18. Describe the red blood cell (RBC) indices and how they are calculated. RBC indices are calculated using values obtained from the CBC, namely the RBC count, hemoglobin, and hematocrit. They assist the physician in diagnosing blood disorders such as anemia.

19. Explain the reasons for performing a white blood cell (WBC) differential. A differential WBC count is performed to assess the numbers and types of WBCs in the blood. A thin smear of whole blood is stained, typically with Wright's stain, and examined microscopically. In addition, the red cells and platelets are examined for distribution and abnormalities.

20. Discuss the Wright's stain sequence. Stains commonly used in blood tests are attracted to different parts of the cell; thus the cells and their structures are more easily seen and differentiated. The most commonly used differential blood stain is Wright's stain. Most Wright's stains today contain mixtures of methylene blue, azure A, thionin, and eosin Y.

21. Describe the appearance of normal erythrocytes. A normal erythrocyte is circular, evenly stained red-purple, and appears to have a hole or depression in the center.

22. Describe the appearance of the five different types of leukocytes seen in a normal Wright-stained differential. The typical leukocytes seen in the differential examination are (1) the segmented neutrophil, which has a segmented blue nucleus and lavender granules in the cytoplasm; (2) the eosinophil, which resembles the neutrophil but has orange granules; (3) the basophil, which resembles the neutrophil but has blue-black granules; (4) the lymphocyte, which is a smaller cell with a light-blue cytoplasm and large dark-blue nucleus; and (5) the monocyte, the largest cell, which has a cerebriform blue nucleus and a light-blue cytoplasm that appears to have bubble-like inclusions.

23. Cite the reasons for performing an erythrocyte sedimentation rate (ESR) test. An ESR test is performed to assess inflammation and often is used to monitor rheumatoid arthritis. This test measures the rate at which RBCs fall in a calibrated tube in a 60-minute period.

24. Describe the sources of error for the erythrocyte sedimentation rate test. An ESR test result may be erroneous if a tube is not standing vertically in the rack; bubbles are present in the Westergren or Wintrobe tube; dilutions are incorrect; vibrations or jarring occur; the blood is at a temperature other than room temperature; and the blood has hemolyzed.

25. Determine an erythrocyte sedimentation rate using a modified Westergren method. Refer to Procedure 54-4.

26. Describe the tests performed to assess coagulation. The PT and PTT are the tests most commonly performed to assess coagulation capacity. The PT test also is routinely performed to assess a patient’s response to anticoagulants such as warfarin (Coumadin).

27. Differentiate between the ABO blood groupings and the Rh blood groupings. Both the ABO blood type and the Rh type result from antigens on the surfaces of RBCs, and both groups are crucial when it comes to transfusion. There are four different ABO types (A, AB, B, and O), but only two Rh types (positive and negative). Corresponding antibodies are present in the blood for the ABO type (e.g., anti-A antibody is found in type B and type O blood); corresponding antibodies are not normally found in the Rh system.

28. Secure a capillary blood sample and determine the ABO and Rh grouping of the sample. Refer to Procedures 54-5 and 54-6.

29. Discuss rare blood types and the implication of having a rare blood type when transfusion is necessary. A rare blood type is one in which the blood group antigen (or lack thereof) is not common in a population. More than 20 blood types other than the ABO and Rh systems exist. Individuals with rare blood types are at risk of developing atypical antibodies when transfused with incompatible blood. These atypical antibodies make future cross-matching more challenging.

30. Describe the methodology behind the clinical chemistry testing methods used in the physician's office laboratory. Four methods generally are used in physician's office laboratory:
   - Lateral flow immunassay: Antigen-antibody reactions result in the deposition of a colored molecule or particle on a solid-phase membrane.
   - Reflectance photometry: A chemical reaction produces a colored product, which has an absorbed wavelength that is detected by an instrument.
   - Amperometry (electrochemistry): An instrument detects the number of electrons generated by a chemical reaction.
   - Chemiluminescence: Electrons generated from a chemical reaction react with a luminescing compound on a test strip, producing a flash of light, which is detected by an instrument.

31. Explain the reasons for testing blood glucose, blood cholesterol, hemoglobin A1c, thyroid hormone levels, and liver enzymes. The blood glucose level is monitored routinely in patients with diabetes type 1 or type 2 and in women who have gestational diabetes during pregnancy. Cholesterol testing generally refers to assessing levels of HDL cholesterol and LDL cholesterol; it is done to help determine a patient’s susceptibility to coronary artery disease. Hemoglobin A1c levels are measured to determine the average blood glucose level during the 2 to 3 months before the test; this test assists in management of diabetes. Thyroid testing is performed in the physician's office laboratory to detect elevated TSH levels and to assist with the diagnosis of hypothyroidism. Liver enzyme testing (ALT and AST) is performed in the physician’s office laboratory primarily to monitor the side effects of certain therapeutic drugs, such as those used to treat elevated cholesterol and diabetes. Refer to Table 54-9.

32. Perform a cholesterol test using a cholesterol monitor approved by the U. S. Food and Drug Administration (FDA). Refer to Procedure 54-7.

33. Summarize typical chemistry panels, the reason for performing each panel, and the individual tests performed in those panels. Certain tests that provide information about a disease or syndrome are grouped together in panels. For example, a liver panel detects abnormalities in a number of different liver enzymes (see Tables 54-10 and 54-11).
CONNECTIONS

Study Guide Connection: Go to the Chapter 54 Study Guide. Read and complete the activities.

Evolve Connection: Go to the Chapter 54 link at evolve.elsevier.com/kilan to complete the Chapter Review and Chapter Quiz. Peruse other resources listed for this chapter to increase your knowledge of Assisting in the Analysis of Blood.