A 47-year-old patient is admitted to an inpatient oncology unit with a new diagnosis of acute myeloid leukemia (AML). She presented to the outpatient office of her primary provider with complaints of flu-like symptoms for the past four weeks, which have worsened over the past three days to now include weakness and dyspnea on exertion. Laboratory tests and a bone marrow biopsy confirmed the diagnosis of AML. The patient is scheduled to begin chemotherapy and a central venous catheter will be placed prior to treatment initiation. Prevention of infection is vital in patients with leukemia. Often patients with AML will not exhibit typical signs of infection such as elevated fever.
The complexities inherent in today’s health care system challenges nurses to demonstrate integration of specific interdisciplinary core competencies. These competencies are aimed at ensuring the delivery of safe, quality patient care (Institute of Medicine, 2003). The Quality and Safety Education for Nurses project (QSEN, 2017; Cronenwett, Sherwood, Barnsteiner, et al., 2007) provides a framework for the knowledge, skills, and attitudes (KSA) required for nurses to demonstrate competency in these key areas, which include patient-centered care, interdisciplinary teamwork and collaboration, evidence-based practice, quality improvement, safety, and informatics.

**Evidence-Based Practice Definition:** Integrate best current evidence with clinical expertise and patient/family preferences and values for delivery of optimal health care.

### QSEN Competency Focus: Evidence-Based Practice (EBP)

The complexities inherent in today’s health care system challenges nurses to demonstrate integration of specific interdisciplinary core competencies. These competencies are aimed at ensuring the delivery of safe, quality patient care (Institute of Medicine, 2003). The Quality and Safety Education for Nurses project (QSEN, 2017; Cronenwett, Sherwood, Barnsteiner, et al., 2007) provides a framework for the knowledge, skills, and attitudes (KSA) required for nurses to demonstrate competency in these key areas, which include patient-centered care, interdisciplinary teamwork and collaboration, evidence-based practice, quality improvement, safety, and informatics.

**Evidence-Based Practice Definition:** Integrate best current evidence with clinical expertise and patient/family preferences and values for delivery of optimal health care.

<table>
<thead>
<tr>
<th>SELECTED PRE-LICENSURE KSAs</th>
<th>APPLICATION AND REFLECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knowledge</strong></td>
<td></td>
</tr>
<tr>
<td>Explain the role of evidence in determining best clinical practice.</td>
<td>What is the strength of the evidence for strategies aimed at preventing infection in patients with AML? Identify the pathophysiologic relationships between the disease process in AML, the susceptibility to infection, and the atypical signs and symptoms of infection in patients with leukemias.</td>
</tr>
<tr>
<td><strong>Skills</strong></td>
<td></td>
</tr>
<tr>
<td>Locate evidence reports related to clinical practice topics and guidelines.</td>
<td>What strategies would you use to search for and then identify appropriate evidence for decreasing rates of infection in patients with AML? What resources might you mobilize to provide education for this patient on the best strategies to prevent infection? What signs and symptoms should she monitor and report to her primary provider?</td>
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<tr>
<td><strong>Attitudes</strong></td>
<td></td>
</tr>
<tr>
<td>Value the need for continuous improvement in clinical practice based on new knowledge.</td>
<td>Reflect on your attitudes toward patients with diseases susceptible to infection. Do you tend to think that infection is inevitable in patients with a cancer diagnosis?</td>
</tr>
</tbody>
</table>


**LEARNING OBJECTIVES**

On completion of this chapter, the learner will be able to:

1. Describe hematopoiesis and the processes involved in maintaining hemostasis.
2. Discuss the significance of the health history to the assessment of hematologic health.
3. Specify the proper techniques utilized to perform a comprehensive physical assessment of hematologic function.
4. Explain the diagnostic tests and related nursing implications used to evaluate hematologic function.
5. Identify therapies for blood disorders, including nursing implications for the administration of blood components.

**GLOSSARY**

- **anemia:** decreased red blood cell (RBC) count
- **band cell:** slightly immature neutrophil
- **blast cell:** primitive white blood cell (WBC)
- **cytokines:** proteins produced by leukocytes that are vital to regulation of hematopoiesis, apoptosis, and immune responses
- **differentiation:** development of functions and characteristics that are different from those of the parent stem cell
- **erythrocyte:** a cellular component of blood involved in the transport of oxygen and carbon dioxide (synonym: red blood cell)
- **erythropoiesis:** process of the formation of RBCs
- **erythropoietin:** hormone produced primarily by the kidney; necessary for erythropoiesis
- **fibrin:** filamentous protein; basis of thrombus and blood clot
- **fibrinogen:** protein converted into fibrin to form thrombus and clot
- **fibrinolysis:** process of breakdown of fibrin clot
- **granulocyte:** granulated WBC (i.e., neutrophil, eosinophil, basophil); sometimes used synonymously with neutrophil
- **hematocrit:** percentage of total blood volume consisting of RBCs
- **hematopoiesis:** complex process of the formation and maturation of blood cells
- **hemoglobin:** iron-containing protein of RBCs; delivers oxygen to tissues
- **hemostasis:** intricate balance between clot formation and clot dissolution
- **histiocytes:** cells present in all loose connective tissue, capable of phagocytosis
- **leukocyte:** one of several cellular components of blood involved in defense of the body; subtypes include neutrophils, eosinophils, basophils, monocytes, and lymphocytes (synonym: white blood cell)
- **leukopenia:** less-than-normal amount of WBCs in circulation
- **lymphocyte:** form of WBC involved in immune functions
- **lymphoid:** pertaining to lymphocytes
- **macrophage:** reticuloendothelial cells capable of phagocytosis
- **monocyte:** large WBC that becomes a macrophage when it leaves the circulation and moves into body tissues
- **myeloid:** pertaining to nonlymphoid blood cells that differentiate into RBCs, platelets, macrophages, mast cells, and various WBCs
- **myelopoiesis:** formation and maturation of cells derived from myeloid stem cell
- **natural killer (NK) cells:** immune cells that accumulate in lymphoid tissue that are potent killers of virus-infected and cancer cells
- **neutrophil:** fully mature WBC capable of phagocytosis; primary defense against bacterial infection
- **nucleated RBC:** immature form of RBC; portion of nucleus remains within the RBC
- **oxyhemoglobin:** combined form of oxygen and hemoglobin; found in arterial blood
- **phagocytosis:** process of cellular ingestion and digestion of foreign bodies
- **plasma:** liquid portion of blood
- **plasminogen:** protein converted to plasmin to dissolve thrombi and clots
- **platelet:** a cellular component of blood involved in blood coagulation (synonym: thrombocyte)
- **red blood cell (RBC):** a cellular component of blood involved in the transport of oxygen and carbon dioxide (synonym: erythrocyte)
- **reticulocytes:** slightly immature RBCs, usually only 1% of total circulating RBCs
- **reticuloendothelial system:** complex system of cells throughout the body capable of phagocytosis
- **serum:** portion of blood remaining after coagulation occurs
- **stem cell:** primitive cell, capable of self-replication and differentiation into myeloid or lymphoid stem cell
- **stroma:** component of the bone marrow not directly related to hematopoiesis but serves important supportive roles in this process
- **thrombocyte:** a cellular component of blood involved in blood coagulation (synonym: platelet)
- **white blood cell (WBC):** one of several cellular components of blood involved in defense of the body; subtypes include neutrophils, eosinophils, basophils, monocytes, and lymphocytes (synonym: leukocyte)
Unlike many other body systems, the hematologic system encompasses the entire human body. Patients with hematologic disorders often have significant abnormalities in blood tests but few or no symptoms. Therefore, the nurse must have a good understanding of the pathophysiology of the patient’s condition and the ability to make a thorough assessment that relies heavily on the interpretation of laboratory tests. It is equally important for the nurse to anticipate potential patient needs and to target nursing interventions accordingly. Because it is so important to the understanding of most hematologic diseases, a basic appreciation of blood cells and bone marrow function is necessary.

**Anatomic and Physiologic Overview**

The hematologic system consists of the blood and the sites where blood is produced, including the bone marrow and the reticuloendothelial system (RES). Blood is a specialized organ that differs from other organs in that it exists in a fluid state. Blood is composed of plasma and various types of cells. Plasma is the fluid portion of blood; it contains various proteins, such as albumin, globulin, fibrinogen, and other factors necessary for clotting, as well as electrolytes, waste products, and nutrients. About 55% of blood volume is plasma (Mescher, 2013).

**Structure and Function of the Hematologic System**

**Blood**

The cellular component of blood consists of three primary cell types (see Table 32-1): erythrocytes (red blood cells [RBCs], red cells), leukocytes (white blood cells [WBCs]), and thrombocytes (platelets). These cellular components of blood normally make up 40% to 45% of the blood volume. Because most blood cells have a short lifespan, the need for the body to replenish its supply of cells is continuous; this process is termed hematopoiesis. The primary site for hematopoiesis is the bone marrow. During embryonic development and in other conditions, the liver and spleen may also be involved.

Under normal conditions, the adult bone marrow produces about 175 billion erythrocytes, 70 billion neutrophils (a mature type of WBC), and 175 billion platelets each day. When the body needs more blood cells, as in infection (when neutrophils are needed to fight the invading pathogen) or in bleeding (when more RBCs are required), the marrow increases its production of the cells required. Thus, under normal conditions, the marrow responds to increased demand and releases adequate numbers of cells into the circulation.

Blood makes up approximately 7% to 10% of the normal body weight and amounts to 5 to 6 L of volume. Circulating through the vascular system and serving as a link between body organs, blood carries oxygen absorbed from the lungs and nutrients absorbed from the gastrointestinal (GI) tract to the body cells for cellular metabolism. Blood also carries hormones, antibodies, and other substances to their sites of action or use. In addition, blood carries waste products produced by cellular metabolism to the lungs, skin, liver, and kidneys, where they are transformed and eliminated from the body.

The danger that trauma can lead to excess blood loss always exists. To prevent this, an intricate clotting mechanism is activated when necessary to seal any leak in the blood vessels. Excessive clotting is equally dangerous, because it can obstruct blood flow to vital tissues. To prevent this, the body has a fibrinolytic mechanism that eventually dissolves clots (thrombi) formed within blood vessels. The balance between these two systems—clot (thrombus) formation and clot dissolution or fibrinolysis—is called hemostasis.

**Bone Marrow**

The bone marrow is the site of hematopoiesis, or blood cell formation. In adults, blood cell formation is usually limited to the pelvis, ribs, vertebrae, and sternum. Marrow is one of the largest organs of the body, making up 4% to 5% of total body weight. It consists of islands of cellular components (red marrow) separated by fat (yellow marrow). As people age, the proportion of active marrow is gradually replaced by fat; however, in healthy adults, the fat can again be replaced by active marrow when more blood cell production is required. In adults with disease that causes marrow destruction, fibrosis, or scarring, the liver and spleen can also resume production of blood cells by a process known as extramedullary hematopoiesis.

The marrow is highly vascular. Within it are primitive cells called stem cells. The stem cells have the ability to self-replicate, thereby ensuring a continuous supply of stem cells throughout the life cycle. When stimulated to do so, stem cells can begin a process of differentiation into either myeloid or lymphoid stem cells (see Fig. 32-1). These stem cells are committed to produce specific types of blood cells. Lymphoid stem cells produce either T or B lymphocytes. Myeloid stem cells differentiate into three broad cell types: erythrocytes, leukocytes, and platelets. Thus, with the exception of lymphocytes, all blood cells are derived from myeloid stem cells. A defect
Hematopoiesis and stromal stem cell differentiation. Uncommitted (pluripotent) stem cells can differentiate into myeloid or lymphoid stem cells. These stem cells then undergo a complex process of differentiation and maturation into normal cells that are released into the circulation. The myeloid stem cell is responsible not only for all nonlymphoid white blood cells but also for the production of red blood cells (RBCs) and platelets. Each step of the differentiation process depends in part on the presence of specific growth factors for each cell type. When the stem cells are dysfunctional, they may respond inadequately to the need for more cells, or they may respond excessively, and sometimes uncontrollably, as in leukemia. From Koury, M., Mahmud, N., & Rhodes, M. (2009). Origin and development of blood cells. In J. P. Greer, J. Foerster, G. M. Rodgers (Eds.). *Wintrobe’s clinical hematology* (12th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.
in a myeloid stem cell can cause problems with erythrocyte, leukocyte, and platelet production. In contrast, a defect in the lymphoid stem cell can cause problems with T or B lymphocytes, plasma cells (a more differentiated form of B lymphocyte), or natural killer (NK) cells. Over 100 billion cells are produced by the marrow each day (Davoren & Wang, 2013).

The stroma of the marrow refers to all tissue within the marrow that is not directly involved in hematopoiesis. However, the stroma is important in an indirect manner, in that it produces the colony-stimulating factors needed for hematopoiesis. The yellow marrow is the largest component of the stroma. Other cells comprising the stroma include fibroblasts (reticular connective tissue), osteoclasts, osteoblasts (both needed for remodeling of skeletal bone), and endothelial cells.

**Blood Cells**

**Erythrocytes (Red Blood Cells)**

The normal erythrocyte is a biconcave disc that resembles a soft ball compressed between two fingers (see Fig. 32-2). It has a diameter of about 8 mcm and is so flexible that it can pass easily through capillaries that may be as small as 2.8 mcm in diameter. The membrane of the red cell is very thin so that gases, such as oxygen and carbon dioxide, can easily diffuse across it; the disc shape provides a large surface area that facilitates the absorption and release of oxygen molecules.

Mature erythrocytes consist primarily of hemoglobin, which contains iron and makes up 95% of the cell mass. Mature erythrocytes have no nuclei, and they have many fewer metabolic enzymes than do most other cells. The presence of a large amount of hemoglobin enables the red cell to perform its principal function, which is the transport of oxygen between the lungs and tissues. Occasionally, the marrow releases slightly immature forms of erythrocytes, called reticulocytes, into the circulation. This occurs as a normal response to an increased demand for erythrocytes (as in bleeding) or in some disease states.

The oxygen-carrying hemoglobin molecule is made up of four subunits, each containing a heme portion attached to a globin chain. Iron is present in the heme component of the molecule. An important property of heme is its ability to bind to oxygen loosely and reversibly. Oxygen readily binds to hemoglobin in the lungs and is carried as oxyhemoglobin in arterial blood. Oxyhemoglobin is a brighter red than hemoglobin that does not contain oxygen (reduced hemoglobin); thus, arterial blood is a brighter red than venous blood. The oxygen readily dissociates (detaches) from hemoglobin in the tissues, where the oxygen is needed for cellular metabolism. In venous blood, hemoglobin combines with hydrogen ions produced by cellular metabolism and thus buffers excessive acid. Whole blood normally contains about 15 g of hemoglobin per 100 mL of blood (Fischbach & Dunning, 2015).

**Erythropoiesis**

Erythroblasts arise from the primitive myeloid stem cells in bone marrow. The erythroblast is an immature nucleated cell that gradually loses its nucleus. At this stage, the cell is known
as a reticulocyte. Further maturation into an erythrocyte entails the loss of the dark-staining material within the cell and slight shrinkage. The mature erythrocyte is then released into the circulation. Under conditions of rapid erythropoiesis (i.e., erythrocyte production), reticulocytes and other immature cells (e.g., nucleated RBCs) may be released prematurely into the circulation. This is often seen when the liver or spleen takes over as the site of erythropoiesis and more nucleated red cells appear within the circulation.

Differentiation of the primitive myeloid stem cell into an erythroblast is stimulated by erythropoietin, a hormone produced primarily by the kidney. If the kidney detects low levels of oxygen, as occurs when fewer red cells are available to bind oxygen (i.e., anemia), or with people living at high altitudes with lower atmospheric oxygen concentrations, erythropoietin levels increase. The increased erythropoietin then stimulates the marrow to increase the production of erythrocytes. The entire process of erythropoiesis typically takes less than 5 days (Papayannopoulou & Migliaccio, 2013). For normal erythrocyte production, the bone marrow also requires iron, vitamin B₁₂, folate, pyridoxine (vitamin B₆), protein, and other factors. A deficiency of these factors during erythropoiesis can result in decreased red cell production and anemia.

Iron Stores and Metabolism
The average daily diet in the United States contains 10 to 15 mg of elemental iron, but only 1 to 2.5 mg of ingested iron is normally absorbed from the small intestine (Adamson, 2015). The rate of iron absorption is regulated by the amount of iron already stored in the body and by the rate of erythrocyte production. Additional amounts of iron, up to 2 mg daily, must be absorbed by women of childbearing age to replace that lost during menstruation. Total body iron content in the average adult is approximately 3 g, most of which is present in hemoglobin or in one of its breakdown products. Iron is stored as ferritin and when required, the iron is released into the plasma, binds to transferrin, and is transported into the membranes of the normoblasts (erythrocyte precursor cells) within the marrow, where it is incorporated into hemoglobin. Iron is lost in the feces, either in bile, blood, or mucosal cells from the intestine.

The concentration of iron in blood is normally about 50 to 150 µg/dl. (Adamson & Longo, 2015). With iron deficiency, bone marrow iron stores are rapidly depleted; hemoglobin synthesis is depressed, and the erythrocytes produced by the marrow are small and low in hemoglobin. Iron deficiency in the adult generally indicates blood loss (e.g., from bleeding in the GI tract or heavy menstrual flow). Lack of dietary iron is rarely the sole cause of iron deficiency anemia in adults. The source of iron deficiency should be investigated promptly, because iron deficiency in an adult may be a sign of bleeding in the GI tract or colon cancer.

Vitamin B₁₂ and Folate Metabolism
Vitamin B₁₂ and folate are required for the synthesis of deoxyribonucleic acid (DNA) in RBCs. Both vitamin B₁₂ and folate are derived from the diet. Folate is absorbed in the proximal small intestine, but only small amounts are stored within the body. If the diet is deficient in folate, stores within the body quickly become depleted. Because vitamin B₁₂ is found only in foods of animal origin, strict vegetarians may ingest little vitamin B₁₂. Vitamin B₁₂ combines with intrinsic factor produced in the stomach. The vitamin B₁₂-intrinsic factor complex is absorbed in the distal ileum. People who have had a partial or total gastrectomy may have limited amounts of intrinsic factor, and therefore the absorption of vitamin B₁₂ may be diminished. The effects of either decreased absorption or decreased intake of vitamin B₁₂ are not apparent for 2 to 4 years.

Vitamin B₁₂ and folate deficiencies are characterized by the production of abnormally large erythrocytes called megaloblasts. Because these cells are abnormal, many are sequestered (trapped) while still in the bone marrow, and their rate of release is decreased. Some of these cells actually die in the marrow before they can be released into the circulation. This results in megaloblastic anemia.

Red Blood Cell Destruction
The average lifespan of a normal circulating erythrocyte is 120 days. Aged erythrocytes lose their elasticity and become trapped in small blood vessels and the spleen. They are removed from the blood by the reticuloendothelial cells, particularly in the liver and the spleen. As the erythrocytes are destroyed, most of their hemoglobin is recycled. Some hemoglobin also breaks down to form bilirubin and is secreted in the bile. Most of the iron is recycled to form new hemoglobin molecules within the bone marrow; small amounts are lost daily in the feces and urine and monthly in menstrual flow.

Leukocytes (White Blood Cells)
Leukocytes are divided into two general categories: granulocytes and lymphocytes. In normal blood, the total leukocyte count is 4000 to 11,000 cells/mm³. Of these, approximately 60% to 80% are granulocytes and 20% to 40% are lymphocytes. Both of these types of leukocytes primarily protect the body against infection and tissue injury.

Granulocytes
Granulocytes are defined by the presence of granules in the cytoplasm of the cell. Granulocytes are divided into three main subgroups—eosinophils, basophils, and neutrophils—that are characterized by the staining properties of these granules (see Fig. 32-2). Eosinophils have bright-red granules in their cytoplasm, whereas the granules in basophils stain deep blue. The third and most numerous cell in this class is the neutrophil, with granules that stain a pink to violet hue. Neutrophils are also called polymorphonuclear neutrophils (PMNs, or polys) or segmented neutrophils (segs).

The nucleus of the mature neutrophil has multiple lobes (usually two to five) that are connected by thin filaments of nuclear material, or a “segmented” nucleus; it is usually two times the size of an erythrocyte. The somewhat less mature granulocyte has a single-lobed, elongated nucleus and is called a band cell. Ordinarily, band cells account for only a small percentage of circulating granulocytes, although their percentage can increase greatly under conditions in which neutrophil production increases, such as infection. The increased number of band cells is sometimes called a left shift or shift to the left. (Traditionally, the diagram of neutrophil maturation showed the myeloid stem cell on the left with progressive maturation stages toward the right, ending with a fully mature neutrophil on the far right side. A shift to the left...
initiate phagocytosis, but they are short-lived. An influx of 1 hour after the onset of an inflammatory reaction and other foreign entities. The major function of neutrophils is phagocytosis, the ingestion and digestion of bacteria and particles. Neutrophils die here within 1 to 2 days. The number of circulating granulocytes found in the healthy person is relatively constant; however, in infection, large numbers of these cells are rapidly released into the circulation.

**Agranulocytes**

**Monocytes** (also called mononuclear leukocytes) are leukocytes with a single-lobed nucleus and a granule-free cytoplasm—hence the term agranulocyte (see Fig. 32-2). In normal adult blood, monocytes account for approximately 5% of the total leukocytes. Monocytes are the largest of the leukocytes. Produced by the bone marrow, they remain in the circulation for a short time before entering the tissues and transforming into macrophages. Macrophages are particularly active in the spleen, liver, peritoneum, and alveoli; they remove debris from these areas and phagocytize bacteria within the tissues.

**Lymphocytes**

Mature lymphocytes are small cells with scanty cytoplasm (see Fig. 32-2). Immature lymphocytes are produced in the marrow from the lymphoid stem cells. A second major source of production is the thymus. Cells derived from the thymus are known as T lymphocytes (or T cells); those derived from the marrow can also be T cells but are more commonly B lymphocytes (or B cells). Lymphocytes complete their differentiation and maturation primarily in the lymph nodes and in the lymphoid tissue of the intestine and spleen after exposure to a specific antigen. Mature lymphocytes are the principal cells of the immune system, producing antibodies and identifying other cells and organisms as “foreign.” Natural killer (NK) cells serve an important role in the body's immune defense system. Like other lymphocytes, NK cells accumulate in the lymphoid tissues (especially spleen, lymph nodes, and tonsils), where they mature. When activated, they serve as potent killers of virus-infected and cancer cells. They also secrete chemical messenger proteins, called cytokines, to mobilize the T and B cells into action.

**Function of Leukocytes**

Leukocytes protect the body from invasion by bacteria and other foreign entities. The major function of neutrophils is phagocytosis. Neutrophils arrive at a given site within 1 hour after the onset of an inflammatory reaction and initiate phagocytosis, but they are short-lived. An influx of monocytes follows; these cells continue their phagocytic activities for long periods as macrophages. This process constitutes a second line of defense for the body against inflammation and infection. Although neutrophils can often work adequately against bacteria without the help of macrophages, macrophages are particularly effective against fungi and viruses. Macrophages also digest senescent (aging or aged) blood cells, primarily within the spleen.

The primary function of lymphocytes is to attack foreign material. One group of lymphocytes (T lymphocytes) kills foreign cells directly or releases lymphokines, substances that enhance the activity of phagocytic cells. T lymphocytes are responsible for delayed allergic reactions, rejection of foreign tissue (e.g., transplanted organs), and destruction of tumor cells. This process is known as cellular immunity. The other group of lymphocytes (B lymphocytes) is capable of differentiating into plasma cells. Plasma cells, in turn, produce antibodies called immunoglobulins (Igs), which are protein molecules that destroy foreign material by several mechanisms. This process is known as humoral immunity.

Eosinophils and basophils function in hypersensitivity reactions. Eosinophils are important in the phagocytosis of parasites. The increase in eosinophil levels in allergic states indicates that these cells are involved in the hypersensitivity reaction; they neutralize histamine. Basophils produce and store histamine as well as other substances involved in hypersensitivity reactions. The release of these substances provokes allergic reactions. See Chapter 35 for further information on the immune response.

**Platelets (Thrombocytes)**

Platelets, or thrombocytes, are not technically cells; rather, they are granular fragments of giant cells in the bone marrow called megakaryocytes (see Fig. 32-2). Platelet production in the marrow is regulated in part by the hormone thrombopoietin, which stimulates the production and differentiation of megakaryocytes from the myeloid stem cell.

Platelets play an essential role in the control of bleeding. They circulate freely in the blood in an inactive state, where they nurture the endothelium of the blood vessels, maintaining the integrity of the vessel. When vascular injury occurs, platelets collect at the site and are activated. They adhere to the site of injury and to each other, forming a platelet plug that temporarily stops bleeding. Substances released from platelet granules activate coagulation factors in the blood plasma and initiate the formation of a stable clot composed of fibrin, a filamentous protein. Platelets have a normal lifespan of 7 to 10 days (Konkle, 2015).

Recently, researchers have discovered an additional role for platelets that is related to inflammatory function. Receptors on the surface of platelets permit them to interact with leukocytes, inflamed endothelium of the vessel, and pathogens (Weyrich, 2014). Through a complex process, activated platelets adhere to neutrophils and monocytes, amplifying the immune response. This process is beneficial in the context of exposure to various pathogens (e.g., bacteria). However, this process is also thought to contribute to the inflammatory injury that may be involved in the development of arthritis, cardiovascular and cerebrovascular diseases, cancer, and progression to sepsis.
Plasma and Plasma Proteins

After cellular elements are removed from blood, the remaining liquid portion is called plasma. More than 90% of plasma is water. The remainder consists primarily of plasma proteins; clotting factors (particularly fibrinogen); and small amounts of other substances, such as nutrients, enzymes, waste products, and gases. If plasma is allowed to clot, the remaining fluid is called serum. Serum has essentially the same composition as plasma, except that fibrinogen and several clotting factors have been removed during the clotting process.

Plasma proteins consist primarily of albumin and globulins. The globulins can be separated into three main fractions (alpha, beta, and gamma), each of which consists of distinct proteins that have different functions. Important proteins in the alpha and beta fractions are the transport globulins and the clotting factors that are made in the liver. The transport globulins carry various substances in bound form in the circulation. For example, thyroid-binding globulin carries thyroxin, and transferrin carries iron. The clotting factors, including fibrinogen, remain in an inactive form in the blood plasma until activated by the clotting cascade. The gamma-globulin fraction refers to the Igs, or antibodies. These proteins are produced by well-differentiated B lymphocytes and plasma cells. The actual fractionation of the globulins can be seen on a specific laboratory test (serum protein electrophoresis).

Albumin is particularly important for the maintenance of fluid balance within the vascular system. Capillary walls are impermeable to albumin, so its presence in the plasma creates an osmotic force that keeps fluid within the vascular space. Albumin, which is produced by the liver, has the capacity to bind to several substances that are transported in plasma (e.g., certain medications, bilirubin, and some hormones). People with impaired hepatic function may have low concentrations of albumin, with a resultant decrease in osmotic pressure and the development of edema.

Reticuloendothelial System (RES)

The RES is composed of special tissue macrophages. When released from the marrow, monocytes spend a short time in the circulation (about 24 hours) and then enter the body tissues. Within the tissues, the monocytes continue to differentiate into macrophages, which can survive for months or years. Macrophages have a variety of important functions. They defend the body against foreign invaders (i.e., bacteria and other pathogens) via phagocytosis. They remove old or damaged cells from the circulation. They stimulate the inflammatory process and present antigens to the immune system (see Chapter 35). Macrophages give rise to tissue histiocytes, including Kupffer cells of the liver, peritoneal macrophages, alveolar macrophages, and other components of the RES. Thus, the RES is a component of many other organs within the body, particularly the spleen, lymph nodes, lungs, and liver.

The spleen is the site of activity for most macrophages. Most of the spleen (75%) is made of red pulp; here, the blood enters the venous sinuses through capillaries that are surrounded by macrophages. Within the red pulp are tiny aggregates of white pulp, consisting of B and T lymphocytes. The spleen sequesters newly released reticulocytes from the marrow, removing nuclear fragments and other materials (e.g., denatured hemoglobin, iron) before the now fully mature erythrocyte returns to the circulation. Although a minority of erythrocytes (less than 5%) pool in the spleen, a significant proportion of platelets (20% to 40%) pool here (Doherty, 2015). If the spleen is enlarged, a greater proportion of red cells and platelets can be sequestered. The spleen is a major source of hematopoiesis in fetal life. It can resume hematopoiesis later in adulthood if necessary, particularly when marrow function is compromised (e.g., in bone marrow fibrosis). The spleen has important immunologic functions as well. It forms substances called opsonins that promote the phagocytosis of neutrophils; it also forms the antibody immunoglobulin M (IgM) after exposure to an antigen.

Hemostasis

Hemostasis is the process of preventing blood loss from intact vessels and of stopping bleeding from a severed vessel, which requires adequate numbers of functional platelets. Platelets nurture the endothelium and thereby maintain the structural integrity of the vessel wall. Two processes are involved in arresting bleeding: primary and secondary hemostasis (see Fig. 32-3).

In primary hemostasis, the severed blood vessel constricts. Circulating platelets aggregate at the site and adhere to the vessel and to one another. An unstable hemostatic plug is formed. For the coagulation process to be correctly activated, circulating inactive coagulation factors must be converted to active forms. This process occurs on the surface of the aggregated platelets at the site of vessel injury.

The end result is the formation of fibrin, which reinforces the platelet plug and anchors it to the injury site. This process is referred to as secondary hemostasis. Blood coagulation is highly complex. It can be activated by the extrinsic pathway (also known as the tissue factor pathway) or the intrinsic pathway (also known as the contact activation pathway). Both pathways are needed for maintenance of normal hemostasis. Many factors are involved in the reaction cascade that forms fibrin. When tissue is injured, the extrinsic pathway is activated by the release of thromboplastin from the tissue. As the result of a series of reactions, prothrombin is converted to thrombin, which in turn catalyzes the conversion of fibrinogen to fibrin. Clotting by the intrinsic or contact activation pathway is activated when the collagen that lines blood vessels is exposed. Clotting factors are activated sequentially until, as with the extrinsic pathway, fibrin is ultimately formed (Camp, 2014). The intrinsic pathway is slower, and this sequence is less often responsible for clotting in response to tissue injury. However, it is important if a noninjured vessel wall comes into contact with lipoproteins (e.g., atherosclerosis) or with bacteria, resulting in a clot that is formed for purposes other than protection from trauma or bleeding.

As the injured vessel is repaired and again covered with endothelial cells, the fibrin clot is no longer needed. The fibrin is digested via two systems: the plasma fibrinolytic system and the cellular fibrinolytic system. The substance plasminogen is required to lyse (break down) the fibrin. Plasminogen, which is present in all body fluids, circulates with fibrinogen and is therefore incorporated into the fibrin clot as it forms. When the clot is no longer needed (e.g., after an injured blood vessel has healed), the plasminogen is activated to form plasmin. Plasmin digests the fibrinogen and fibrin. The breakdown particles of the clot, called fibrin degradation products, are released.
into the circulation. Through this system, clots are dissolved as tissue is repaired, and the vascular system returns to its normal baseline state.

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**Gerontologic Considerations**

In older adults, the bone marrow’s ability to respond to the body’s need for blood cells (erythrocytes, leukocytes, and platelets) may be decreased, resulting in leukopenia (a decreased number of circulating leukocytes) or anemia. This decreased ability is a result of many factors, including diminished production of the growth factors necessary for hematopoiesis by stromal cells within the marrow or a diminished response to the growth factors (in the case of erythropoietin). Over time, stem cells within the marrow acquire damage to their DNA, which compromises their function. T and B cell development is also decreased (Snoeck, 2013). Therefore, the development of myeloid malignancies, such as acute myeloid leukemia (AML, see Chapter 34), is more common in older adults. In addition, in older patients, the bone marrow may be more susceptible to the myelosuppressive effects of medications. As a result of these factors, when an older adult needs more blood cells, the bone marrow may not be able to increase the production of these cells adequately.

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**Assessment**

**Health History**

A careful health history and physical assessment can provide important information related to a patient’s known or potential hematologic diagnosis. Because many hematologic disorders are more prevalent in certain ethnic groups, assessments of ethnicity and family history are useful (see Chart 32-1). Similarly, obtaining a nutritional history and assessing the use of prescription and over-the-counter medications, as well as herbal supplements, are important to note, because several conditions can result from nutritional deficiencies, or from the use of certain herbs or medications. Careful attention to the onset of a symptom or finding (e.g., rapid vs. gradual; persistent vs. intermittent), its severity, and any contributing factors can further differentiate potential causes. Of equal importance is assessing the impact of these findings on the patient’s functional ability, manifestations of distress, and coping mechanisms.

**Physical Assessment**

The physical assessment should be comprehensive and include careful attention to the skin, oral cavity, lymph nodes, and spleen (see Fig. 32-4). Table 32-2 highlights a general approach to the physical assessment findings in hematologic disorders (more specific findings are presented in Chapters 33 and 34).

**Diagnostic Evaluation**

Most hematologic diseases reflect a defect in the hematopoietic, hemostatic, or RES. The defect can be quantitative (e.g., increased or decreased production of cells), qualitative (e.g., the cells that are produced are defective in their normal functional capacity), or both. Initially, many hematologic conditions cause few symptoms, and extensive laboratory tests are often required to establish a diagnosis. For most hematologic conditions, continued monitoring via specific blood tests is required because it is very important to assess for changes in test results over time. In general, it is important to assess trends in test results because these trends help the clinician decide whether the patient is responding appropriately to interventions.

**Hematologic Studies**

The most common tests used are the complete blood count (CBC) and the peripheral blood smear. The CBC identifies the total number of blood cells (leukocytes, erythrocytes, and platelets) as well as the hemoglobin, hematocrit (percentage of blood volume consisting of erythrocytes), and RBC...
Hematologic disorders are marked by aberrations in the structure or function of the blood cells or the blood clotting mechanism. Some examples of genetic hematologic disorders are:

**Autosomal Dominant:**
- Factor V Leiden
- Familial hypercholesterolemia
- Hereditary angioedema
- Hereditary spherocytosis
- Von Willebrand disease

**Autosomal Recessive:**
- Hemochromatosis
- Sickle cell disease
- Thalassemia

**X Linked:**
- Hemophilia

### Nursing Assessments

Refer to Chart 5-2: Genetics in Nursing Practice: Genetic Aspects of Health Assessment

**Family History Assessment Specific to Hematologic Disorders**
- Collect family history information on maternal and paternal relatives from three generations of the family.
- Assess family history for other family members with histories of blood disorders or episodes of abnormal bleeding.
- If a family history or personal risk is suspected, the person should be carefully screened for bleeding disorders prior to surgical procedures.

**Patient Assessment Specific to Hematologic Disorders**
- Assess for specific symptoms of hematologic diseases:
  - Extreme fatigue (the most common symptom of hematologic disorders)
  - Delayed clotting of blood
  - Easy or deep bruising
  - Abnormal bleeding (e.g., frequent nosebleeds)
  - Abdominal pain (hemochromatosis) or joint pain (sickle cell disease)
- Review blood cell counts for abnormalities.
- Assess for presence of illness despite low risk for the illness (e.g., a young adult with a blood clot)

### Resources

Hemophilia Federation of America, www.hemophiliafed.org
Sickle Cell Association of America, www.sicklecelldisease.org
See Chapter 8, Chart 8-7 for components of genetic counseling.

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### Lymphatic System

**Figure 32-4** Lymphatic system. Arrows indicate sites of lymph nodes accessible for palpation. Developed by Thomas, M., & Morrow, K. (2011). Veterans Administration Palo Alto Health Care System.

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indices. Because cellular morphology (shape and appearance of the cells) is particularly important in accurately diagnosing most hematologic disorders, the blood cells involved must be examined. This process is referred to as the manual examination of the peripheral smear, which may be part of the CBC. In this test, a drop of blood is spread on a glass slide, stained, and examined under a microscope. The shape and size of the erythrocytes and platelets, as well as the actual appearance of the leukocytes, provide useful information in identifying hematologic conditions. Blood for the CBC is typically obtained by venipuncture (Fischbach & Dunning, 2015).

Other common tests of coagulation are the prothrombin time (PT), typically replaced by the standardized test, international normalized ratio (INR), and the activated partial thromboplastin time (aPTT). The INR and aPTT serve as useful screening tools for evaluating a patient’s clotting ability and monitoring the therapeutic effectiveness of anticoagulant medications. In both tests, specific reagents are mixed into the plasma sample, and the time taken to form a clot is measured. For these tests to be accurate, the test tube must be filled with the correct amount of the patient’s blood; either excess or inadequate blood volume within the tube can render the results inaccurate.

### Bone Marrow Aspiration and Biopsy

Bone marrow aspiration and biopsy are crucial when additional information is needed to assess how a patient’s blood cells are being formed and to assess the quantity and quality of each type of cell produced within the marrow. These tests are also used to document infection or tumor within the marrow. Other specialized tests can be performed on the marrow aspirate, such as cytogenetic analysis or immunophenotyping.
**TABLE 32-2  Health History and Physical Assessment in Hematologic Disorders**

<table>
<thead>
<tr>
<th>Findings</th>
<th>Potential Indications of Hematologic Disorder</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Health History</strong></td>
<td></td>
</tr>
<tr>
<td>Prior episodes of bleeding (epistaxis, tooth, gum, hematuria, menorrhagia, hematochezia, gastrointestinal bleeding and/or ulcers)</td>
<td>Thrombocytopenia, coagulopathy, anemia</td>
</tr>
<tr>
<td>Prior blood clots, pulmonary emboli, miscarriages</td>
<td>Thrombotic disorder</td>
</tr>
<tr>
<td>Fatigue and weakness</td>
<td>Anemia, infection, malignancy, clonal disorders</td>
</tr>
<tr>
<td>Dyspnea, particularly dyspnea on exertion, orthopnea, shortness of breath</td>
<td>Anemia, infection</td>
</tr>
<tr>
<td>Prior radiation therapy (especially pelvic irradiation)</td>
<td>Anemia, pancytopenia, myelodysplastic syndrome, leukemia</td>
</tr>
<tr>
<td>Prior chemotherapy</td>
<td>Myelodysplastic syndrome, leukemia</td>
</tr>
<tr>
<td>Hobbies (occupational/military exposure history (especially benzene, Agent Orange)</td>
<td>Myelodysplastic syndrome, leukemia, myeloma, lymphoma</td>
</tr>
<tr>
<td>Diet history</td>
<td>Anemia (due to vitamin B&lt;sub&gt;12&lt;/sub&gt;, folate, iron deficiency)</td>
</tr>
<tr>
<td>Alcohol consumption</td>
<td>Anemia (effect on hematopoiesis, nutritional deficiency)</td>
</tr>
<tr>
<td>Use of herbal supplements</td>
<td>Platelet dysfunction</td>
</tr>
<tr>
<td>Concurrent medications</td>
<td>Neutropenia, anemia, hemolysis, thrombocytopenia</td>
</tr>
<tr>
<td>Family history/ethnicity</td>
<td>Some hematologic disorders have a higher prevalence in certain ethnic groups and families (see Chapter 32-1)</td>
</tr>
<tr>
<td><strong>Physical Assessment</strong></td>
<td></td>
</tr>
<tr>
<td>Skin</td>
<td></td>
</tr>
<tr>
<td>Gray-tan or bronze skin color (especially genitalia, scars, exposed areas)</td>
<td>Hemochromatosis (primary or secondary)</td>
</tr>
<tr>
<td>Ruddy complexion (face, conjunctiva, hands, feet)</td>
<td>Polythemia</td>
</tr>
<tr>
<td>Ecchymoses (i.e., bruises)</td>
<td>Thrombocytopenia, coagulopathy</td>
</tr>
<tr>
<td>Petechiae (i.e., point hemorrhagic lesions, usually more prominent on trunk or anterior aspects of lower extremities)</td>
<td>Severe thrombocytopenia</td>
</tr>
<tr>
<td>Rash</td>
<td>Variable; if pruritic, may indicate polycythemia, other nonhematologic-related disorders (see Chapter 60)</td>
</tr>
<tr>
<td>Bleeding (including around vascular lines, tubes)</td>
<td>Thrombocytopenia, coagulopathy</td>
</tr>
<tr>
<td>Conjunctival hemorrhage</td>
<td>Severe thrombocytopenia</td>
</tr>
<tr>
<td>Pallor, especially in mucous membranes (including conjunctiva), nail beds</td>
<td>Anemia</td>
</tr>
<tr>
<td>Jaundice in mucous membranes (including conjunctiva), nail beds, palate</td>
<td>Hemolysis</td>
</tr>
<tr>
<td><strong>Oral cavity</strong></td>
<td></td>
</tr>
<tr>
<td>Petechiae in the buccal mucosa, gingiva, hard palate</td>
<td>Severe thrombocytopenia</td>
</tr>
<tr>
<td>Ulceration of oral mucosa</td>
<td>Infection, leukemia</td>
</tr>
<tr>
<td>Tongue: Smooth</td>
<td>Pernicious anemia</td>
</tr>
<tr>
<td>Beefy red</td>
<td>Vitamin B&lt;sub&gt;12&lt;/sub&gt;/folate deficiency</td>
</tr>
<tr>
<td>Enlarged</td>
<td>Amyloidosis</td>
</tr>
<tr>
<td>Angular cheilosis (ulceration at corners of mouth)</td>
<td>Anemia</td>
</tr>
<tr>
<td>Enlarged gums: hyperplasia</td>
<td>Leukemia</td>
</tr>
<tr>
<td>Lymph nodes</td>
<td>Leukemia, lymphoma</td>
</tr>
<tr>
<td><strong>Respiratory</strong></td>
<td></td>
</tr>
<tr>
<td>Increased rate and depth of respirations; adventitious breath sounds</td>
<td>Anemia; infection</td>
</tr>
<tr>
<td><strong>Cardiovascular</strong></td>
<td></td>
</tr>
<tr>
<td>Distended neck veins, edema, chest pain on exertion, murmurs, gallbladder</td>
<td>Severe anemia</td>
</tr>
<tr>
<td>Hypotension (below baseline)</td>
<td>Polycythemia</td>
</tr>
<tr>
<td>Hypertension (above baseline)</td>
<td></td>
</tr>
<tr>
<td><strong>Genitourinary</strong></td>
<td></td>
</tr>
<tr>
<td>Hematuria</td>
<td>Hemolysis, thrombocytopenia</td>
</tr>
<tr>
<td>Proteinuria</td>
<td>Myeloma</td>
</tr>
<tr>
<td><strong>Musculoskeletal</strong></td>
<td></td>
</tr>
<tr>
<td>Rib/ternal tenderness to palpation</td>
<td>Leukemia, myeloma</td>
</tr>
<tr>
<td>Back pain; tenderness to palpation over spine, loss of height, kyphosis</td>
<td>Myeloma</td>
</tr>
<tr>
<td>Pain/swelling in knees, wrists, hands</td>
<td>Hemophilia, sickle cell disease</td>
</tr>
<tr>
<td><strong>Abdominal</strong></td>
<td></td>
</tr>
<tr>
<td>Enlarged spleen</td>
<td>Leukemia, myelofibrosis</td>
</tr>
<tr>
<td>Enlarged liver</td>
<td>Myelofibrosis</td>
</tr>
<tr>
<td>Stool positive for occult blood</td>
<td>Anemia, thrombocytopenia</td>
</tr>
<tr>
<td><strong>Central nervous system</strong></td>
<td></td>
</tr>
<tr>
<td>Cranial nerve dysfunction</td>
<td>Vitamin B&lt;sub&gt;12&lt;/sub&gt; deficiency</td>
</tr>
<tr>
<td>Peripheral nerve dysfunction (especially sensory)</td>
<td>Vitamin B&lt;sub&gt;12&lt;/sub&gt; deficiency, amyloidosis, myeloma</td>
</tr>
<tr>
<td>Visual changes, headache, alteration in mental status</td>
<td>Severe thrombocytopenia</td>
</tr>
<tr>
<td><strong>Gynecologic</strong></td>
<td></td>
</tr>
<tr>
<td>Menorrhagia</td>
<td>Thrombocytopenia, coagulopathy</td>
</tr>
<tr>
<td><strong>Constitutional</strong></td>
<td></td>
</tr>
<tr>
<td>Fever, chills, sweats, asthenia</td>
<td>Leukemia, lymphoma, infection</td>
</tr>
</tbody>
</table>

*Common findings (obtained via health history and physical assessment) that occur in patients with hematologic disorders. Note that signs and symptoms are not disease specific but are useful in guiding the nurse to establishing an etiology for the findings noted.*
(i.e., identifying specific proteins expressed by cells), which are useful in further identifying certain malignant conditions and, in some instances, establishing a prognosis.

Normal bone marrow is in a semifluid state and can be aspirated through a special large needle. In adults, bone marrow is usually aspirated from the iliac crest and occasionally from the sternum. The aspirate provides only a sample of cells. Aspirate alone may be adequate for evaluating certain conditions, such as anemia. However, when more information is required, a biopsy is also performed. Biopsy samples are taken from the posterior iliac crest; occasionally, an anterior approach is required. A marrow biopsy shows the architecture of the bone marrow as well as its degree of cellularity.

Patient preparation includes a careful explanation of the procedure, which may be done at the patient's bedside (for a hospitalized patient) or in the outpatient setting. Some patients may be anxious, thus an antianxiety agent may be prescribed. It is always important for the physician or nurse to describe and explain to the patient the procedure and the sensations that will be experienced. The risks, benefits, and alternatives are also discussed. A signed informed consent is needed before the procedure is performed.

Before aspiration, the skin is cleansed using aseptic technique. Then, a small area is anesthetized with a local anesthetic agent through the skin and subcutaneous tissue to the periosteum of the bone. It is not possible to anesthetize the bone itself. The bone marrow needle is introduced with a stylet in place. When the needle is felt to go through the outer cortex of bone and enter the marrow cavity, the stylet is removed, a syringe is attached, and a small volume (5 mL) of blood and marrow is aspirated. Patients typically feel a pressure sensation as the needle is advanced into position. The actual aspiration always causes sharp but brief pain, resulting from the suction exerted as the marrow is aspirated into the syringe; the patient should be warned about this. Taking deep breaths or using relaxation techniques often helps ease the discomfort (see Fig. 32-5).

If a bone marrow biopsy is necessary, it is best performed after the aspiration and in a slightly different location, because the marrow structure may be altered after aspiration (Ryan, 2015). A special biopsy needle is used. Because these needles are large, the skin may be punctured first with a surgical blade to make a 3- to 4-mm incision. The biopsy needle is advanced well into the marrow cavity. When the needle is properly positioned, a portion of marrow is cored out. The patient feels a pressure sensation but should not feel actual pain. The nurse should assist the patient in maintaining a comfortable position and encourage relaxation and deep breathing throughout the procedure. The patient should be instructed to inform the physician if pain occurs so that an additional anesthetic agent can be given.

Potential complications of either bone marrow aspiration or biopsy include bleeding and infection. The risk of bleeding is somewhat increased if the patient's platelet count is low or if the patient has been taking a medication (e.g., aspirin) that alters platelet function. After the marrow sample is obtained, pressure is applied to the site for several minutes. The site is then covered with a sterile dressing. Most patients have no discomfort after a bone marrow aspiration, but the site of a

![Figure 32-5 • Bone marrow aspiration procedure. The posterior superior iliac crest is the preferred site for bone marrow aspiration and biopsy because no vital organs or vessels are nearby. The patient is placed either in the lateral position with one leg flexed or in the prone position. The anterior iliac crest or sternum may also be used. Note that the sternum cannot be used for a marrow biopsy.](image-url)
biopsy may ache for 1 or 2 days. Warm tub baths and a mild analgesic agent (e.g., acetaminophen [Tylenol]) may be useful. Aspirin-containing analgesic agents should be avoided in the immediate postprocedure period because they can aggravate or potentiate bleeding.

**Unfolding Patient Stories: Lloyd Bennett • Part 1**

Lloyd Bennett is a 76-year-old male who fell while working outdoors. He presents to the Emergency Department with a hip fracture. What physical assessment and laboratory data can assist the nurse in evaluation for possible internal blood loss from the fracture or indications that the patient is at higher risk of bleeding? (Lloyd Bennett’s story continues in Chapter 53.)

Care for Lloyd and other patients in a realistic virtual environment: vsim for Nursing (thepoint.lww.com/vSimMedicalSurgical). Practice documenting these patients’ care in DocuCare (thepoint.lww.com/DocuCareEHR).

**Therapeutic Approaches to Hematologic Disorders**

**Splenectomy**

The surgical removal of the spleen (splenectomy) is a possible treatment for some hematologic disorders. For example, an enlarged spleen may be the site of excessive destruction of blood cells. In addition, some patients with grossly enlarged spleens develop severe thrombocytopenia as a result of platelet destruction from a donor than can be provided from a single unit of whole blood. A unit of platelets obtained in this way is equivalent to 6 to 8 units of platelets obtained from six to eight separate donors via standard blood donation methods. Platelet donors can have their platelets apheresed as often as every 14 days. Leukocytes can be obtained similarly, typically after the donor has received growth factors (granulocyte colony-stimulating factor, granulocyte-macrophage colony-stimulating factor) to stimulate the formation of additional leukocytes and thereby increase the leukocyte count. The use of these growth factors also stimulates the growth of other blood cell types.

**TABLE 32-3** Types of Apheresis*

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Purpose</th>
<th>Examples of Clinical Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plateletpheresis</td>
<td>Remove platelets</td>
<td>Extreme thrombocytosis, essential thrombocytopenia (temporary measure); single-donor platelet transfusion</td>
</tr>
<tr>
<td>Leukopheresis</td>
<td>Remove WBCs (can be specific to neutrophils or lymphocytes)</td>
<td>Extreme leukocytosis (e.g., AML, CML) (very temporary measure); harvest WBCs for transfusion</td>
</tr>
<tr>
<td>Erythrocytapheresis (RBC exchange)</td>
<td>Remove RBCs</td>
<td>RBC dyscrasias (e.g., sickle cell disease); RBCs replaced via transfusion</td>
</tr>
<tr>
<td>Plasmapheresis (plasma exchange)</td>
<td>Remove plasma proteins</td>
<td>Hyperviscosity syndromes; treatment for some renal and neurologic diseases (e.g., Goodpasture syndrome, TTP; Guillain-Barré, myasthenia gravis)</td>
</tr>
<tr>
<td>Stem cell harvest</td>
<td>Remove circulating stem cells</td>
<td>Transplantation (donor harvest or autologous)</td>
</tr>
</tbody>
</table>

*Therapeutic apheresis can be used to treat a wide variety of conditions. When it is used to treat a disease that causes an increase in a specific cell type with a short life in circulation (i.e., WBCs, platelets), the reduction in those cells is temporary. However, this temporary reduction permits a margin of safety while waiting for a longer-lasting treatment modality (e.g., chemotherapy) to take effect. Apheresis can also be used to obtain stem cells for transplantation, either from a matched donor (allogeneic) or from the patient (autologous).

release of stem cells within the circulation. Apheresis is used to harvest these stem cells (typically over a period of several days) for use in peripheral blood stem cell transplant.

### Hematopoietic Stem Cell Transplantation

Hematopoietic stem cell transplantation (HSCT) is a therapeutic modality that offers the possibility of cure for some patients with hematologic disorders such as severe aplastic anemia, some forms of leukemia, and thalassemia. It can also provide longer remission from disease even when cure is not possible, such as in multiple myeloma. Hematopoietic stem cells may be transplanted from either allogeneic or autologous donors. For most hematologic diseases, allogeneic transplant is more effective (Fakih, Shah, & Nieto, 2016); here, stem cells are obtained from a donor whose cell surface antigens match those of the patient. In contrast, the patient’s own stem cells are harvested and then used in autologous transplant. (See Chapter 15 for a detailed discussion of HSCT.)

### Therapeutic Phlebotomy

Therapeutic phlebotomy is the removal of a certain amount of blood under controlled conditions. Patients with elevated hematocrits (e.g., those with polycythemia vera) or excessive iron absorption (e.g., hemochromatosis) can usually be managed by periodically removing 1 unit (about 500 mL) of whole blood. Over time, this process can produce iron deficiency, leaving the patient unable to produce as many erythrocytes. The actual procedure for therapeutic phlebotomy is similar to that for blood donation (see later discussion).

### Blood Component Therapy

A single unit of whole blood contains 450 mL of blood and 50 mL of an anticoagulant, which can be processed and dispersed for administration. However, it is more appropriate, economical, and practical to separate that unit of whole blood into its primary components: erythrocytes, platelets, and plasma (leukocytes are rarely used; see later discussion). Because the plasma is removed, a unit of packed red blood cells (PRBCs) is very concentrated (hematocrit approximately 70%) (Butterworth, Mackey, & Wasnick, 2013).

Each component must be processed and stored differently to maximize the longevity of the viable cells and factors within it; thus, each individual blood component has a different storage life. PRBCs are stored at 4°C (39.2°F). With special preservatives, they can be stored safely for up to 42 days before they must be discarded (American Red Cross, 2015a).

In contrast, platelets must be stored at room temperature because they cannot withstand cold temperatures, and they last for only 5 days before they must be discarded. To prevent clumping, platelets are gently agitated while stored. Plasma is immediately frozen to maintain the activity of the clotting factors within; it lasts for 1 year if it remains frozen. Alternatively, plasma can be further pooled and processed into blood derivatives, such as albumin, immune globulin, factor VIII, and factor IX. Table 32-4 describes each blood component and how it is commonly used.

### Special Preparations

Factor VIII concentrate (antihemophilic factor) is a lyophilized, freeze-dried concentrate of pooled fractionated human plasma. It is used in treating hemophilia A. Factor IX concentrate (prothrombin complex) is similarly prepared and contains factors II, VII, IX, and X. It is used primarily for the treatment of factor IX deficiency (hemophilia B). Factor IX concentrate is also useful in treating congenital factor VII and factor X deficiencies. Recombinant forms of factor VIII, such as Humate-P or Alphanate, are also useful. Because they contain von Willebrand factor, these agents are used in von Willebrand disease as well as in hemophilia A, particularly when patients develop factor VIII inhibitors.

Plasma albumin is a large protein molecule that usually stays within vessels and is a major contributor to plasma oncotic pressure. This protein is used to expand the blood volume of patients in hypovolemic shock and, rarely, to increase the concentration of circulating albumin in patients with hypoalbuminemia.

Immune globulin is a concentrated solution of the antibody immunoglobulin G (IgG), prepared from large pools of plasma. It contains very little immunoglobulin A (IgA) or IgM. Intravenous immunoglobulin (IVIG) is used in various clinical situations to replace inadequate amounts of IgG in patients who are at risk for recurrent bacterial infection (e.g., those with chronic lymphocytic leukemia, those receiving HSCT). It is also used in certain autoimmune disorders, such as idiopathic thrombocytopenic purpura (ITP). Albumin, antihemophilic factors, and IVIG, in contrast to all other fractions of human blood, cells, or plasma, can survive being subjected to heating at 60°C (140°F) for 10 hours to free them of the viral contaminants that may be present.

### Procuring Blood and Blood Products

#### Blood Donation

To protect both the donor and the recipients, all prospective donors are examined and interviewed before they are allowed to donate their blood. The intent of the interview is to assess the general health status of the donor and to identify risk factors that might harm a recipient of the donor’s blood. There is no upper age limit to donation. The American Red Cross (2015b) requires that donors be in good health and meet specific eligibility criteria related to medications and vaccinations, medical conditions and treatments, travel outside the United States, lifestyle and life events, and so on. Detailed information about these criteria is available on the American Red Cross Web site (see the Resources section). All donors are expected to meet the following minimal requirements (American Red Cross, 2015b):

- **Body weight** should be at least 50 kg (110 lb) for a standard 450-mL donation.
- **People younger** than 17 years require parental consent in some states.
- The **oral temperature** should not exceed 37.5°C (99.6°F).
- The systolic arterial blood pressure should be **80 to 180 mm Hg**, and the diastolic pressure should be **50 to 100 mm Hg**.
- The hemoglobin level should be at least 12.5 g/dL.
Directed Donation

At times, friends and family of a patient wish to donate blood for that person. These blood donations are referred to as directed donations. These donations are not any safer than those provided by random donors, because directed donors may not be as willing to identify themselves as having a history of any of the risks factors that disqualify a person from donating blood. Therefore, many blood centers no longer accept directed donations.

Standard Donation

Phlebotomy consists of venipuncture and blood withdrawal. Standard precautions are used. Donors are placed in a semirecumbent position. The skin over the antecubital fossa is carefully cleansed with an antiseptic preparation, a tourniquet is applied, and venipuncture is performed. Withdrawal of 450 mL of blood usually takes less than 15 minutes. After the needle is removed, donors are asked to hold the involved arm straight up, and firm pressure is applied with sterile gauze for 2 to 3 minutes. A firm bandage is then applied. The donor remains recumbent until he or she feels able to sit up, usually within a few minutes. Donors who experience weakness or faintness should rest for a longer period. The donor then receives food and fluids and is asked to remain another 15 minutes.

The donor is instructed to leave the dressing on and to avoid heavy lifting for several hours, to avoid smoking for 1 hour, to avoid drinking alcoholic beverages for 3 hours, to increase fluid intake for 2 days, and to eat healthy meals for at least 2 weeks. Specimens from the donated blood are tested to detect infections and to identify the specific blood type (see later discussion).

Autologous Donation

A patient’s own blood may be collected for future transfusion; this method is useful for many elective surgeries where the potential need for transfusion is high (e.g., orthopedic surgery). Preoperative donations are ideally collected 4 to 6 weeks before surgery. Iron supplements are prescribed during this period to prevent depletion of iron stores. Typically, 1 unit of blood is drawn each week; the number of units obtained varies with the type of surgical procedure to be

### TABLE 32-4 Blood and Blood Components Commonly Used in Transfusion Therapy

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
<th>Indications and Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole blood</td>
<td>Cells and plasma, hematocrit about 40%</td>
<td>Volume replacement and oxygen-carrying capacity; usually used only in significant bleeding (≥25% blood volume lost)</td>
</tr>
<tr>
<td>PRBCs</td>
<td>RBCs with little plasma (hematocrit about 75%); some platelets and WBCs remain</td>
<td>↑ RBC mass; symptomatic anemia: • Platelets within the unit are not functional • WBCs within the unit may cause reaction and are not functional</td>
</tr>
<tr>
<td>Platelets—random</td>
<td>Platelets (5.5 × 10^11 platelets/unit), plasma; some RBCs, WBCs</td>
<td>Bleeding due to ↓ platelets Prevent bleeding when platelets &lt;5,000–10,000/mm^3 Survival ↓ in presence of fever, chills, infection Repeated treatment leads to ↓ survival due to alloimmunization.</td>
</tr>
<tr>
<td>Platelets—single donor</td>
<td>Platelets (3 × 10^11 platelets/unit)</td>
<td>Used for repeated treatment: • ↓ alloimmunization risk by limiting exposure to multiple donors</td>
</tr>
<tr>
<td>Plasma</td>
<td>Plasma; all coagulation factors</td>
<td>Bleeding in patients with coagulation factor deficiencies; plasmapheresis</td>
</tr>
<tr>
<td>Granulocytes</td>
<td>Neutrophils (&gt;1 × 10^11/unit); some lymphocytes, RBCs, and platelets will remain within the unit.</td>
<td>Severe neutropenia in selected patients; controversial</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>Lymphocytes (number varies)</td>
<td>Stimulate graft-versus-host disease effect</td>
</tr>
<tr>
<td>Cryoprecipitate</td>
<td>Fibrinogen ≥150 mg/bag, AHF (VIII:C) 80–110 units/bag, von Willebrand factor; fibronec tin</td>
<td>von Willebrand disease Hypofibrinogemina Hemophilia A</td>
</tr>
<tr>
<td>AHF</td>
<td>Factor VIII</td>
<td>Hemophilia A</td>
</tr>
<tr>
<td>Factor IX complex</td>
<td>Factors II, VII, IX, X</td>
<td>Hemophilia B (Christmas disease)</td>
</tr>
<tr>
<td>Factor IX concentrate</td>
<td>Factor IX</td>
<td>Hereditary factor VII, IX, X deficiency; hemophilia A with factor VII inhibitors</td>
</tr>
<tr>
<td>Albumin</td>
<td>Albumin 5%, 25%</td>
<td>Hypoprothrombinemia; burns; volume expansion by 5% to ↑ blood volume; 25% leads to ↓ hematocrit</td>
</tr>
<tr>
<td>IV gamma-globulin</td>
<td>Immunoglobulin G antibodies</td>
<td>Hypogammaglobulinemia (in CLL, recurrent infections); ITP; primary immunodeficiency states</td>
</tr>
<tr>
<td>Antithrombin III concentrate (AT III)</td>
<td>AT III (trace amounts of other plasma proteins)</td>
<td>AT III deficiency with or at risk for thrombosis</td>
</tr>
</tbody>
</table>

performed (i.e., the amount of blood anticipated to be transfused). Phlebotomies are not performed within 72 hours of surgery. Individual blood components can also be collected.

The primary advantage of autologous transfusions is the prevention of viral infections from another person's blood. Other advantages include safe transfusion for patients with a history of transfusion reactions, prevention of alloimmunization, and avoidance of complications in patients with alloantibodies. It is the policy of the American Red Cross that autologous blood is transfused only to the donor. If the blood is not required, it can be frozen until the donor needs it in the future (for up to 10 years). The blood is never returned to the general donor supply of blood products to be used by another person.

Needless autologous donation (i.e., performed when the likelihood of transfusion is small) is discouraged because it is expensive, takes time, and uses resources inappropriately. Moreover, in an emergency situation, the autologous units available may be inadequate, and the patient may still require additional units from the general donor supply. Furthermore, although autologous transfusion can eliminate the risk of viral contamination, the risk of bacterial contamination is the same as that in transfusion from random donors (Stowell & Hass, 2014).

Contraindications to donation of blood for autologous transfusion are acute infection, severely debilitating chronic disease, hemoglobin level less than 11 g/dL, unstable angina, and acute cardiovascular or cerebrovascular disease. A history of poorly controlled epilepsy may be considered a contraindication in some centers.

**Intraoperative Blood Salvage**

This transfusion method provides replacement for patients who cannot donate blood before surgery and for those undergoing vascular, orthopedic, or thoracic surgery. During a surgical procedure, blood lost into a sterile cavity (e.g., hip joint) is suctioned into a cell-saver machine. The whole blood or PRBCs are washed, often with saline solution; filtered; and then returned to the patient as an IV infusion. Salvaged blood cannot be stored because bacteria cannot be completely removed from the blood and thus cannot be used when it is contaminated with bacteria. The use of intraoperative blood salvage has decreased the need for autologous blood donation but has not affected the need for allogeneic blood products (Vonk, Meesters, Garnier, et al., 2013).

**Hemodilution**

This transfusion method may be initiated before or after induction of anesthesia. About 1 to 2 units of blood are removed from the patient through a venous or arterial line and simultaneously replaced with a colloid or crystalloid solution. The blood obtained is then infused after surgery. The advantage of this method is that the patient loses fewer erythrocytes during surgery, because the added IV solutions dilute the concentration of erythrocytes and lower the hematocrit. However, patients who are at risk for myocardial injury should not be further stressed by hemodilution. Hemodilution has been associated with adverse outcomes in patients having cardiopulmonary bypass; it has also been linked to tissue ischemia, particularly in the kidneys (Mehta, Castelvecchio, Ballotta, et al., 2013).

**Complications of Blood Donation**

Excessive bleeding at the donor’s venipuncture site is sometimes caused by a bleeding disorder but more often results from a technique error: laceration of the vein, excessive tourniquet pressure, or failure to apply enough pressure after the needle is withdrawn.

Fainting may occur after blood donation and may be related to emotional factors, a vasovagal reaction, or prolonged fasting before donation (McCullough, Refaai, & Cohn, 2015). Because of the loss of blood volume, hypotension and syncope may occur when the donor assumes an erect position. A donor who appears pale or complains of faintness should immediately lie down or sit with the head lowered below the knees. He or she should be observed for another 30 minutes.

Anginal chest pain may be precipitated in patients with unsuspected coronary artery disease. Seizures can occur in donors with epilepsy, although the incidence is very low. Both angina and seizures require further medical evaluation and treatment.

**Blood Processing**

Samples of the unit of blood are always taken immediately after donation so that the blood can be typed and tested. Each donation is tested for antibodies to human immune deficiency virus (HIV) types 1 and 2, hepatitis B core antibody (anti-HBc), hepatitis C virus (HCV), human T-cell lymphotropic virus type I (anti-HTLV-I/II), hepatitis B surface antigen (HbsAg), and syphilis. Negative reactions are required for the blood to be used, and each unit of blood is labeled to certify the results. Nucleic acid amplification testing has increased the ability to detect the presence of HCV, HIV, and West Nile virus infections, because it directly tests for genomic nucleic acids of the viruses rather than for the presence of antibodies to the viruses. This testing significantly shortens the “window” of inability to detect HIV and HCV from a donated unit, further ensuring the safety of the blood; the risk of transmission of HIV or HCV is now estimated at 1 in 2 million units and 1 in 1.6 million units of blood donated, respectively (American Cancer Society, 2013). Blood is also screened for cytomegalovirus (CMV). If it tests positive for CMV, it can still be used, except in recipients who are negative for CMV and who are severely immunocompromised; any components are labeled as CMV positive.

Equally important is accurate determination of the blood type. More than 200 antigens have been identified on the surface of RBC membranes. Of these, the most important for safe transfusion are the ABO and Rh systems. The ABO system identifies which sugars are present on the membrane of a person's erythrocytes: A, B, both A and B, or neither A nor B (type O). To prevent a significant reaction, the same type of PRBCs should be transfused. Previously, it was thought that in an emergency situation in which the patient’s blood type was not known, type O blood could be safely transfused. This practice is no longer recommended.

The Rh antigen (also referred to as D) is present on the surface of erythrocytes in 85% of the population (Rh positive). Those who lack the D antigen are referred to as being Rh negative. PRBCs are routinely tested for the D antigen as well as ABO. Patients should receive PRBCs with a compatible Rh type.

The majority of transfusion reactions are due to clerical error where the patient is transfused an incompatible unit of blood product (McCullough et al., 2015). Reactions (other
than those due to procedural error) are most frequently due to the presence of donor leukocytes within the blood component unit (PRBCs or platelets); the recipient may form antibodies to the antigens present on these leukocytes. PRBC components typically have 1 to 3 \( \times 10^7 \) leukocytes remaining in each unit. Leukocytes from the blood product are frequently filtered to diminish the likelihood of developing reactions and refractoriness to transfusions, particularly in patients who have chronic transfusion needs. The process of leukocyte filtration renders the blood component “leukocyte poor” (i.e., leukopenic). Filtration can occur at the time the unit is collected from the donor and processed, which achieves better results but is more expensive, or at the time the blood component is transfused by attaching a leukocyte filter to the blood administration tubing. Many centers advocate routinely using leukopenic filtered blood components for people who have or are likely to develop chronic transfusion requirements.

When a patient is immunocompromised, as in the case following stem cell transplant, any donor lymphocytes must be removed from the blood components. In this situation, the blood component is exposed to low amounts of radiation (25 Gy) that kill any lymphocytes within the blood component. Irradiated blood products are highly effective in preventing transfusion-associated graft-versus-host disease, which is fatal in most cases. Irradiated blood products have a shorter shelf life.

**Transfusion**

Administration of blood and blood components requires knowledge of correct administration techniques and possible complications. It is very important to be familiar with the agency’s policies and procedures for transfusion therapy. Methods for transfusing blood components are presented in Charts 32-2 and 32-3.

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**Chart 32-2**

**Transfusion of Packed Red Blood Cells**

**Preprocedure**

1. Confirm that the transfusion has been prescribed.
2. Check that patient’s blood has been typed and cross-matched.
3. Verify that patient has signed a written consent form per institution or agency policy and agrees to procedure.
4. Explain procedure to patient. Instruct patient in signs and symptoms of transfusion reaction (itching, hives, swelling, shortness of breath, fever, chills).
5. Take patient’s temperature, pulse, respiration, blood pressure and assess fluid volume status (e.g., auscultate lungs, assess for jugular venous distention) to serve as a baseline for comparison during transfusion.
6. Note if signs of increased fluid overload present (e.g., heart failure, see Chapter 29), contact primary provider to discuss potential need for a prescription for diuretic, as warranted.
7. Use hand hygiene and wear gloves in accordance with standard precautions.
8. Use appropriately sized needle for insertion in a peripheral vein.

*a* Use special tubing that contains a blood filter to screen out fibrin clots and other particulate matter. Do not vent blood container.

**Procedure**

1. Obtain packed red blood cells (PRBCs) from the blood bank after the IV line is started. (Institution policy may limit release to only 1 unit at a time.)
2. Double-check labels with another nurse or physician to ensure that the ABO group and Rh type agree with the compatibility record. Check to see that number and type on donor blood label and on patient’s medical record are correct. Confirm patient’s identification by asking the patient’s name and checking the identification wristband.
3. Check blood for gas bubbles and any unusual color or cloudiness. (Gas bubbles may indicate bacterial growth. Abnormal color or cloudiness may be a sign of hemolysis.)

**Note:** Never add medications to blood or blood products; if blood is too thick to run freely, normal saline may be added to the unit. If blood must be warmed, use an in-line blood warmer with a monitoring system.

*a* Most policies stipulate using an IV with a minimum of 20 gauge. A recent evidence-based synthesis did not find increased hemolysis when packed red cells are infused through a small-gauge needle (Stupnyckyj, Smolarek, Reeves, et al., 2014).


**Postprocedure**

1. Obtain vital signs and breath sounds; compare with baseline measurements. If signs of increased fluid overload present (e.g., heart failure, see Chapter 29), consider obtaining prescription for diuretic as warranted.
2. Dispose of used materials properly.
3. Document procedure in patient’s medical record, including patient assessment findings and tolerance to procedure.
4. Monitor patient for response to and effectiveness of procedure. If patient is at risk, monitor for at least 6 hours for signs of transfusion-associated circulatory overload (TACO); also monitor for signs of delayed hemolytic reaction.

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*American Journal of Nursing*
The patient history is an important component of the pre-transfusion assessment. Components (e.g., factor VIII for patients with hemophilia).

Typically, patients who need chronic transfusions but are otherwise stable physically are appropriate candidates for outpatient therapy. Verification and administration of the blood product are performed as in a hospital setting. Although most patients’ homes may be appropriate settings for transfusion.

Most blood transfusions are performed in the acute care setting, and sometimes must be done emergently. However, the processes utilized to ensure safe transfusion of blood cannot be abridged for the sake of rapidity; all procedural details outlined in Chart 32-2 must be followed, including obtaining informed consent (see Chart 32-4).

Patients with chronic transfusion requirements often can receive transfusions in other settings. Freestanding infusion centers, ambulatory care clinics, physicians’ offices, and even patients’ homes may be appropriate settings for transfusion. Typically, patients who need chronic transfusions but are otherwise stable physically are appropriate candidates for outpatient therapy. Verification and administration of the blood product are performed as in a hospital setting. Although most blood products can be transfused in the outpatient setting, the home is typically limited to transfusions of PRBCs and factor components (e.g., factor VIII for patients with hemophilia).

**Pretransfusion Assessment**

**Patient History**

The patient history is an important component of the pretransfusion assessment to determine the history of previous transfusions as well as previous reactions to transfusion. The history should include the type of reaction, its manifestations, the interventions required, and whether any preventive interventions were used in subsequent transfusions. The nurse assesses the number of pregnancies a woman has had, because a high number can increase her risk of reaction due to antibodies developed from exposure to fetal circulation. Other concurrent health problems should be noted, with careful attention to cardiac, pulmonary, and vascular disease.

**Physical Assessment**

A systematic physical assessment and measurement of baseline vital signs and fluid status are important before transfusing any blood product. The respiratory system should be assessed, including careful auscultation of the lungs and the patient’s use of accessory muscles. Cardiac system assessment should include careful inspection for any edema as well as other signs of heart failure (e.g., jugular venous distention; see Chapter 29). The skin should be observed for rashes, petechiae, and ecchymoses. The sclera should be examined for icterus. In the event of a transfusion reaction, a comparison of findings can help differentiate between types of reactions.
**Case Scenario**

An 18-year-old male is admitted with severe bleeding due to a stab wound. The surgeon states that the patient will need to receive several units of blood products to stabilize him. When he is presented with the informed consent, he refuses to sign because of his religious convictions. The surgeon states, “If you were my son, I would insist that you sign.” His mother is adamant that he receives the blood, because the surgeon has told her that her son will likely die of his injuries without the transfusions. The patient acknowledges that he fully understands the consequences of his failure to consent and refuses. The patient dies as a result of hypovolemic shock.

**Discussion**

A patient’s religious and cultural beliefs may significantly impact their decision whether to consent to a procedure such as a blood transfusion. Differences in moral perspectives can complicate the provision of quality nursing care. The patient who has mental capacity, is fully informed of the benefits and risks of a procedure, and is at least 18 years of age has the right to sign or refuse consent to a procedure. In the case presented, the patient’s decision to refuse blood transfusions is a result of his religious convictions.

**Febrile Nonhemolytic Reaction**

A febrile nonhemolytic reaction is caused by antibodies to donor leukocytes that remain in the unit of blood or blood component; it is the most common type of transfusion reaction (Dzieczkowski & Anderson, 2015). It occurs more frequently in patients who have had previous transfusions (exposure to multiple antigens from previous blood products) and in Rh-negative women who have borne Rh-positive children (exposure to an Rh-positive fetus raises antibody levels in the untreated mother).

The diagnosis of a febrile nonhemolytic reaction is made by excluding other potential causes, such as a hemolytic reaction or bacterial contamination of the blood product. The signs and symptoms of a febrile nonhemolytic transfusion reaction are chills (minimal to severe) followed by fever (more than 1°C elevation). The fever typically begins within 2 hours after the transfusion has begun. Although the reaction is not life-threatening, the fever, and particularly the chills and muscle stiffness, can be frightening to the patient.

This reaction can be diminished, even prevented, by further depleting the blood component of donor leukocytes; this is accomplished by a leukocyte reduction filter. Antipyretic agents can be given to prevent fever; however, routine premedication is not advised because it can mask the beginning of a more serious transfusion reaction.

**Acute Hemolytic Reaction**

The most dangerous, and potentially life-threatening, type of transfusion reaction occurs when the donor blood is incompatible with that of the recipient (i.e., type II hypersensitivity reaction). Antibodies already present in the recipient’s plasma rapidly combine with antigens on donor erythrocytes, and the erythrocytes are destroyed in the circulation (i.e., intravascular hemolysis). The most rapid hemolysis occurs in ABO incompatibility. Rh incompatibility often causes a less severe reaction. This reaction can occur after transfusion of as little
as 10 mL of PRBCs. Although the overall incidence of such reactions is not high (1:20,000 to 1:40,000 units transfused) (McCullough et al., 2015), they are largely preventable. The most common causes of acute hemolytic reaction are errors in blood component labeling and patient identification that result in the administration of an ABO-incompatible transfusion.

Symptoms consist of fever, chills, low back pain, nausea, chest tightness, dyspnea, and anxiety. As the erythrocytes are destroyed, the hemoglobin is released from the cells and excreted by the kidneys; therefore, hemoglobin appears in the urine (hemoglobinuria). Hypotension, bronchospasm, and vascular collapse may result. Diminished renal perfusion results in acute kidney injury, and disseminated intravascular coagulation may also occur. The reaction must be recognized promptly and the transfusion discontinued immediately (see the Nursing Management for Transfusion Reactions section).

Acute hemolytic transfusion reactions are preventable. Meticulous attention to detail in labeling blood samples and blood components and accurately identifying the recipient cannot be overstated. Bar coding methods can be useful safeguards in matching a patient’s wristband with the label on the blood component; however, these methods are not fail proof and do not reduce the nurse’s responsibility to ensure the correct blood component is transfused to the correct patient (Hurrell, 2014).

Allergic Reaction
Some patients develop urticaria (hives) or generalized itching during a transfusion; the cause is thought to be a sensitivity reaction to a plasma protein within the blood component being transfused. Symptoms of an allergic reaction are urticaria, itching, and flushing. The reactions are usually mild and respond to antihistamines. If the symptoms resolve after administration of an antihistamine (e.g., diphenhydramine [Benadryl]), the transfusion may be resumed. Rarely, the allergic reaction is severe, with bronchospasm, laryngeal edema, and shock. These reactions are managed with epinephrine, corticosteroids, and vasopressor support, if necessary.

Giving the patient antihistamines or corticosteroids before the transfusion may prevent future reactions. For severe reactions, future blood components are washed to remove any remaining plasma proteins. Leukocyte filters are not useful to prevent such reactions, because the offending plasma proteins can pass through the filter.

Transfusion-Associated Circulatory Overload (TACO)
If too much blood is infused too quickly, hypervolemia can occur. This condition can be aggravated in patients who already have increased circulatory volume (e.g., those with heart failure, renal dysfunction, advanced age, acute myocardial infarction) (Alam et al., 2013). A careful assessment for signs of circulatory overload or positive fluid status prior to initiating the transfusion is required, particularly in those individuals at risk for developing transfusion-related acute lung injury (TRALI). PRBCs are safer to use than whole blood. If the administration rate is sufficiently slow, circulatory overload may be prevented.

For patients who are at risk for, or already in, circulatory overload, diuretics are given prior to the transfusion or between units of PRBCs. Patients receiving fresh-frozen plasma or even platelets may also develop circulatory overload. The infusion rate of these blood components must also be titrated to the patient’s tolerance. Rates of transfusion may need to decrease to less than 100 to 120 mL/hr (Alam et al., 2013).

Signs of circulatory overload include dyspnea, orthopnea, tachycardia, an increase in blood pressure, and sudden anxiety. Jugular vein distention, crackles at the base of the lungs, and hypoxemia will also develop. Pulmonary edema can quickly develop, as manifested by severe dyspnea and coughing of pink, frothy sputum.

If fluid overload is mild, the transfusion can often be continued after slowing the rate of infusion and administering diuretics. However, if the overload is severe, the patient is placed upright with the feet in a dependent position, the transfusion is discontinued, and the primary provider is notified. The IV line is kept patent with a very slow infusion of normal saline solution or a saline lock device to maintain access to the vein in case IV medications are necessary. Oxygen and morphine may be needed to treat severe dyspnea (see Chapter 29).

TACO can develop as late as 6 hours after transfusion (Alam et al., 2013). Therefore, patients need close monitoring after the transfusion is complete, particularly those who are at higher risk for developing this complication (e.g., older adults, those with a positive fluid balance prior to transfusion, patients with renal dysfunction, patients with left ventricular dysfunction). Monitoring vital signs, auscultating breath sounds, and assessing for jugular venous distention should be included in patient monitoring.

Bacterial Contamination
The incidence of bacterial contamination of blood components is very low; however, administration of contaminated products puts the patient at great risk. Contamination can occur at any point during procurement or processing but often results from organisms on the donor’s skin. Many bacteria cannot survive in the cold temperatures used to store PRBCs, but some organisms can do so. Platelets are at greater risk of contamination because they are stored at room temperature. In response to this, blood centers have developed rapid methods of culturing platelet units, thereby diminishing the risk of using a contaminated platelet unit for transfusion (Centers for Disease Control and Prevention, 2013).

Preventive measures include meticulous care in the procurement and processing of blood components. When PRBCs or whole blood is transfused, it should be given within a 4-hour period, because warm room temperatures promote bacterial growth. A contaminated unit of blood product may appear normal, or it may have an abnormal color.

The signs of bacterial contamination are fever, chills, and hypotension. These manifestations may not occur until the transfusion is complete, occasionally not until several hours after the transfusion. As soon as the reaction is recognized, any remaining transfusion is discontinued (see the Nursing Management for Transfusion Reactions section). If the
condition is not treated immediately with fluids and broad-spectrum antibiotics, sepsis can occur. Sepsis is treated with IV fluids and antibiotics; corticosteroids and vasopressors are often also necessary (see Chapter 14).

Transfusion-Related Acute Lung Injury (TRALI)
TRALI is a potentially fatal, idiosyncratic reaction that is defined as the development of acute lung injury occurring within 6 hours after the blood transfusion. All blood components have been implicated in TRALI, including IVIG, cryoprecipitate, and stem cells. TRALI is the most common cause of transfusion-related death (Alam et al., 2013).

The underlying pathophysiologic mechanism for TRALI is unknown but is thought to involve specific human leukocyte antigen (HLA) or human neutrophil antigen (HNA) antibodies in the donor’s plasma that react to the leukocytes in the recipient’s blood. Occasionally, the reverse occurs, and antibodies present in the recipient’s plasma agglutinate the antigens on the few remaining leukocytes in the blood component being transfused. Another theory suggests that an initial insult to the patient’s vascular endothelium can predispose the neutrophils to aggregate at the injured endothelium. Various substances within the transfused blood component (lipids, cytokines) then activate these neutrophils. Each of these pathophysiologic mechanisms can contribute to the process. The end result of this process is interstitial and intra-alveolar edema, as well as extensive sequestration of WBCs within the pulmonary capillaries (Bockhold & Crumpler, 2015).

Onset is abrupt (usually within 6 hours of transfusion, often within 2 hours). Signs and symptoms include acute shortness of breath, hypoxia (arterial oxygen saturation \[\text{SaO}_2\] less than 90%; partial pressure of arterial oxygen \[\text{PAO}_2\] to fraction of inspired oxygen \[\text{FiO}_2\] ratio of less than 300), hypotension, fever, and eventual pulmonary edema. Diagnostic criteria include hypoxemia, bilateral pulmonary infiltrates (seen on chest x-ray), no evidence of cardiac cause for the pulmonary edema, and no other plausible alternative cause within 6 hours of completing transfusion. Aggressive supportive therapy (e.g., oxygen, intubation, fluid support) may prevent death. Immunological therapy (e.g., corticosteroids) has not been shown to be effective in this setting; diuretics can worsen the situation (Bockhold & Crumpler, 2015; Kenz & van der Linden, 2014).

Although TRALI can occur with the transfusion of any blood component, it is more likely to occur when plasma and, to a lesser extent, platelets are transfused. One commonly used preventive strategy involves limiting the frequency and amount of blood products transfused. Another entails obtaining plasma and possibly platelets only from men because women who have been pregnant may have developed offending antibodies. A third strategy involves screening donors for the presence of these antibodies and discarding any plasma-containing blood products from those donors who screen positive. The efficacy of these approaches in preventing TRALI remains unclear (Alam et al., 2013).

Delayed Hemolytic Reaction
Delayed hemolytic reactions usually occur within 14 days after transfusion, when the level of antibody has been increased to the extent that a reaction can occur. The hemolysis of the erythrocytes is extravascular via the RES and occurs gradually.

Signs and symptoms of a delayed hemolytic reaction are fever, anemia, increased bilirubin level, decreased or absent haptoglobin, and possibly jaundice. Rarely, there is hemoglobinuria. Generally, these reactions are not dangerous, but it is important to recognize them because subsequent transfusions with blood products containing these antibodies may cause a more severe hemolytic reaction. However, recognition is also difficult because the patient may not be in a health care setting to be tested for this reaction, and even if the patient is hospitalized, the reaction may be too mild to be recognized clinically. Because the amount of antibody present can be too low to detect, it is difficult to prevent delayed hemolytic reactions. Fortunately, the reaction is usually mild and requires no intervention.

Disease Acquisition
Despite advances in donor screening and blood testing, certain diseases can still be transmitted by transfusion of blood components (see Chart 32-5).

Complications of Long-Term Transfusion Therapy
The complications that have been described represent a real risk to any patient any time a blood component is given. However, patients with long-term transfusion requirements (e.g., those with myelodysplastic syndrome, thalassemia, aplastic anemia, sickle cell disease) are at greater risk for infection transmission and for becoming more sensitized to donor antigens, simply because they are exposed to more units of blood and, consequently, more donors. A summary of complications associated with long-term transfusion therapy is given in Table 32-5.

Iron overload is a complication unique to people who have had long-term PRBC transfusions. One unit of PRBCs contains 250 mg of iron. Patients with chronic transfusion requirements can quickly acquire more iron than they can use, leading to iron overload. Over time, the excess iron deposits in body tissues can cause organ damage, particularly in the liver, heart, testes, and pancreas. Promptly initiating a program of iron chelation therapy can prevent end-organ damage from iron toxicity (see Chapter 33, Hereditary Hemochromatosis, Nursing Management, and Chapter 34, Myelodysplastic Syndrome, Nursing Management).

Nursing Management for Transfusion Reactions
If a transfusion reaction is suspected, the transfusion must be stopped immediately and the primary provider notified. A thorough patient assessment is crucial, because many complications have similar signs and symptoms. The following steps are taken to determine the type and severity of the reaction:

- Stop the transfusion. Maintain the IV line with normal saline solution through new IV tubing, given at a slow rate.
- Assess the patient carefully. Compare the vital signs with baseline, including oxygen saturation. Assess the patient’s respiratory status carefully. Note the presence of adventitious breath sounds; the use of accessory
Chart 32-5  Diseases Potentially Transmitted by Blood Transfusion

**Hepatitis (Viral Hepatitis B, C)**
- There is greater risk from pooled blood products and blood of paid donors than from volunteer donors.
- A screening test detects most hepatitis B and C.
- Transmittal risk for Hepatitis B is estimated at 1:350,000 donated units.

**AIDS (HIV and HTLV)**
- Donated blood is screened for antibodies to HIV.
- Transmittal risk is estimated at 1:1.5 million donated units.
- People with high-risk behaviors (multiple sex partners, anal sex, IV/injection drug use) and people with signs and symptoms that suggest AIDS should not donate blood.

**Cytomegalovirus (CMV)**
- Transmittal risk is greater for premature newborns with CMV antibody–negative mothers and for immunocompromised recipients who are CMV negative (e.g., those with acute leukemia, organ or tissue transplant recipients).
- Blood products rendered “leukocyte reduced” help reduce transmission of virus.

AIDS, acquired immunodeficiency syndrome; HIV, human immunodeficiency virus; HTLV, human T-lymphotropic virus.


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**Graft-Versus-Host Disease (GVHD)**
- GVHD occurs only in severely immunocompromised recipients (e.g., Hodgkin disease, bone marrow transplantation).
- Transfused lymphocytes engraft in recipient and attack host lymphocytes or body tissues; signs and symptoms are fever, diffuse reddened skin rash, nausea, vomiting, and diarrhea.
- Preventive measures include irradiating blood products to inactivate donor lymphocytes (no known radiation risks to transfusion recipient) and processing donor blood with leukocyte reduction filters.

**Creutzfeldt-Jakob Disease (CJD)**
- CJD is a rare, fatal disease that causes irreversible brain damage.
- There is no evidence of transmittal by transfusion.
- All blood donors must be screened for positive family history of CJD.
- Potential donors who spent a cumulative time of 5 years or more (January 1980 to present) in certain areas of Europe cannot donate blood; blood products from a donor who develops CJD are recalled.

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**Common Complications Resulting from Long-Term Packed Red Blood Cell Transfusion Therapy**

**TABLE 32-5**  Common Complications Resulting from Long-Term Packed Red Blood Cell Transfusion Therapy

<table>
<thead>
<tr>
<th>Complication</th>
<th>Manifestation</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection</td>
<td>Hepatitis (B, C)</td>
<td>May immunize against hepatitis B, treat hepatitis C; monitor hepatic function</td>
</tr>
<tr>
<td>Iron overload</td>
<td>CMV</td>
<td>WBC filters to protect against CMV</td>
</tr>
<tr>
<td></td>
<td>Heart failure</td>
<td>Prevent by chelation therapy</td>
</tr>
<tr>
<td></td>
<td>Endocrine failure (diabetes, hypothyroidism, hypoparathyroidism, hypogonadism)</td>
<td></td>
</tr>
<tr>
<td>Transfusion reaction</td>
<td>Sensitization</td>
<td>Diminish by RBC phenotyping, using WBC-filtered products</td>
</tr>
<tr>
<td></td>
<td>Febrile reactions</td>
<td>Diminish by using WBC-filtered products</td>
</tr>
</tbody>
</table>

CMV, cytomegalovirus; WBC, white blood cell; RBC, red blood cell.

*Patients with long-term transfusion therapy requirements are at risk not only for the transfusion reactions discussed in the text but also for the complications noted in the table.

In many cases, the use of WBC-filtered (i.e., leukocyte-poor) blood products is standard for patients who receive long-term packed RBC transfusion therapy. An aggressive transfusion program initiated early in the course of therapy can prevent problems with iron overload.

Pharmacologic Alternatives to Blood Transfusions

Growth Factors

Recombinant technology has provided a means to produce hematopoietic growth factors necessary for the production of blood cells within the bone marrow. By increasing the body’s production of blood cells, transfusions and complications resulting from diminished blood cells (e.g., infection from neutropenia) may be avoided. However, the successful use of growth factors requires functional bone marrow. Moreover, the safety of these products has been questioned, and the U.S. Food and Drug Administration is limiting their use in some patient populations.

Erythropoietin

Erythropoietin (epoetin alfa [Epoegen, Procrit]; darbepoietin [Aranesp]) is an effective alternative treatment for patients with chronic anemia secondary to diminished levels of erythropoietin, as in chronic renal disease. This medication stimulates erythropoiesis. It also has been used for patients who are anemic from chemotherapy or zidovudine (AZT) therapy and for those who have diseases involving bone marrow suppression, such as myelodysplastic syndrome (MDS). The use of erythropoietin can also enable a patient to donate several units of blood for future use (e.g., preoperative autologous donation). The medication can be administered IV or subcutaneously, although plasma levels are better sustained with the subcutaneous route. Side effects are rare, but erythropoietin can cause or exacerbate hypertension. If the anemia is corrected too quickly or is overcorrected, the elevated hematocrit can cause headache and, potentially, seizures. Thrombosis has been noted in some patients whose hemoglobins were raised to a high level; thus, it is recommended that a target hemoglobin level of less than 12 g/dl be used. These adverse effects are rare except for patients with renal failure. Serial complete blood counts (CBCs) must be performed to evaluate the response to the medication. The dose and frequency of administration are titrated to the hemoglobin level.

Granulocyte-Colony-Stimulating Factor (G-CSF)

G-CSF (filgrastim [Neupogen, Zarxio, Granix]) is a cytokine that stimulates the proliferation and differentiation of myeloid stem cells; a rapid increase in neutrophils is seen within the circulation. G-CSF is effective in improving transient but severe neutropenia after chemotherapy or in some forms of MDS. It is particularly useful in preventing bacterial infections that would be likely to occur with neutropenia. G-CSF is given subcutaneously on a daily basis. The primary side effect is bone pain; this probably reflects the increase in hematopoiesis within the marrow. Serial CBCs should be performed to evaluate the response to the medication and to ensure that the rise in white blood cells is not excessive. The effect of G-CSF on myelopoesis is short; the neutrophil count drops once the medication is stopped.

Granulocyte-Macrophage Colony-Stimulating Factor (GM-CSF)

GM-CSF (sargramostim [Leukine]) is a cytokine that is naturally produced by a variety of cells, including monocytes and endothelial cells. It works either directly or synergistically with other growth factors to stimulate myelopoiesis. GM-CSF is not as specific to neutrophils as is G-CSF; thus, an increase in erythroid (red blood cell) and megakaryocytic (platelet) production may also be seen. GM-CSF serves the same purpose as G-CSF. However, it may have a greater effect on macrophage function and therefore may be more useful against fungal infections, whereas G-CSF may be better used to fight bacterial infections. GM-CSF is also given subcutaneously. Side effects include bone pain, fevers, and myalgias.

Thrombopoietin

Thrombopoietin (TPO) is a cytokine that is necessary for the proliferation of megakaryocytes and subsequent platelet formation. Nonimmunogenic second-generation thrombopoietic growth factors (romiplostim [Nplate]; eltrombopag [Promacta]) are used for the treatment of idiopathic thrombocytopenic purpura. Eptrombopag is also approved for use in certain situations for patients with aplastic anemia and in patients requiring hepatitis C treatment that can cause significant thrombocytopenia.

You are caring for a 72-year-old male patient admitted to a medical unit with an exacerbation of chronic obstructive pulmonary disease. He is anemic, and you are transfusing him with 2 units of PRBCs. The second unit is almost completed when he complains of more shortness of breath and appears anxious. His pulse is 118 bpm, respirations 28 per minute, BP 104/60, and temperature 37.2°C (99°F). What might be the etiology of his respiratory distress? How will you distinguish between TACO, hemolytic transfusion reaction, and further exacerbation of his underlying pulmonary disease? What are the appropriate interventions to initiate? How will you prioritize your care for this patient?