Blood circulation is necessary to transport substances required for tissue cellular metabolism, eliminate metabolic waste products, provide defense against invading microorganisms and injuries, and regulate acid-base balance.

Anemia is a disorder characterized by a deficiency in the number of red blood cells or a decrease in the quantity of hemoglobin in the blood. Red blood cells and hemoglobin are crucial for transporting oxygen from the lungs to the body's tissues and organs.

<u>Oxygen Transportation</u>

- From tissues
- O_2 binds to hemoglobin and CO_2 released for exhaling
  - Pulmonary alveolus
- Hemoglobin in red blood cells (RBCs) transports O_2 to tissues
  - Hemoglobin
  - O_2 molecule
- O_2 released to cells and CO_2 absorbed to be carried back to lungs
- To lungs

Anemia is a reduction in the oxygen-carrying capacity of blood due to a lack of circulating red blood cells or a decrease in the quality or quantity of hemoglobin. A normal hemoglobin level is 12.0–17.0 g/dL. The client has a low hemoglobin level; therefore, the NP should expect the client to exhibit clinical manifestations of anemia such as weakness, fatigue, pallor, muscle pain, increased respiratory rate, exertional dyspnea, dizziness, and fainting.

<u>Hypertension and bradycardia are not associated with anemia.</u>

When arterial oxygen levels are low, the kidneys increase production and excretion of erythropoietin to stimulate the bone marrow to increase red blood cell production.

Red blood cells are produced within the bone marrow through the process of erythropoiesis:

- Decreased arterial oxygen levels results in tissue hypoxia.
- Tissue hypoxia stimulates the kidneys to increase production and excretion of erythropoietin.
- Erythropoietin binds to erythropoietin receptors in the bone marrow, resulting in increased production of red blood cells.
- An increase in red blood cells often corrects tissue hypoxia.
- Improved tissue hypoxia signals the kidneys to reduce production and excretion of erythropoietin to a normal level.

When the serum erythropoietin level is high, it is anticipated that the hematocrit will be low, and when the serum erythropoietin level is low, it is anticipated that the hematocrit will be high.

Increased production and excretion of erythropoietin is stimulated by tissue hypoxia, associated with low hemoglobin and hematocrit levels. When hemoglobin and hematocrit levels are normal, the production and excretion of erythropoietin returns to normal levels. When hemoglobin and hematocrit levels are high, the production and excretion of erythropoietin is low.

NORMAL RED BLOOD CELL PRODUCTION

Erythrocytes are red blood cells that transport gas to and from the lungs and tissue cells. Adequate supplies of protein, vitamins, and minerals are necessary for normal erythrocyte production.

Red blood cells are produced within the bone marrow through the process of erythropoiesis:

- Decreased arterial oxygen levels result in tissue hypoxia.
- Tissue hypoxia stimulates the kidneys to increase the production and excretion of erythropoietin.
- Erythropoietin binds to erythropoietin receptors in the bone marrow, resulting in increased production of red blood cells.
- An increase in the production of red blood cells often corrects tissue hypoxia.
- Improved tissue hypoxia signals the kidneys to reduce the production and excretion of erythropoietin to a normal level.

Relationship between erythropoietin and hematocrit: When the hematocrit and oxygen levels are low, there will be an increase in the production of erythropoietin. When the hematocrit and oxygen levels are high, there will be a decrease in the production of erythropoietin.

PATHOPHYSIOLOGY OF ANEMIA

Anemia is characterized by a reduction in the oxygen-carrying capacity of blood due to a lack of circulating red blood cells or a decrease in the quality or quantity of hemoglobin. A range of underlying problems cause anemia. Identifying the cause of anemia is foundational to treating the problem. Causes include acute or chronic blood loss, impaired erythrocyte production, increased erythrocyte destruction, or a combination of these factors.

- Anemia can be caused by acute or chronic blood loss such as trauma or gastrointestinal tract lesions.
- Anemia can be caused by impaired red blood cell production due to inherited genetic defects or nutritional deficiencies.
  - An example of an inherited genetic defect that causes anemia is thalassemia syndrome.
  - Examples of nutritional deficiencies that can cause anemia include B12 and folate deficiencies, iron deficiencies, renal failure, acute leukemia, or endocrine disorders.
- Anemia can be caused by hemolysis due to inherited genetic defects or acquired genetic defects.
  - Examples of anemias caused by inherited genetic defects include red cell membrane disorders like hereditary spherocytosis, enzyme deficiencies like pyruvate kinase deficiency, or hemoglobin abnormalities like thalassemia syndrome or sickle cell disease.
  - Examples of anemia caused by acquired genetic defects include antibody-mediated destruction like hemolytic disease of the newborn (Rh disease), transfusion reactions, and autoimmune disorders; infection such as malaria; or cardiac traumatic hemolysis caused by defective cardiac valves.

Anemia can be caused by acute or chronic blood loss, impaired erythrocyte production, increased erythrocyte destruction, or a combination of these factors. Gastrointestinal tract lesions such as esophageal varices can cause anemia. Nutritional deficiencies from following a strict vegan diet or anorexia can cause anemia. Inherited genetic defects like sickle cell disease can cause anemia.

Polycythemia is an increased level of red blood cells.

ANEMIA CLASSSIFICATION: SIZE

Anemias are classified by the size and color of the red blood cells. Determining the size and color of the red blood cells is an important step in identifying the type and source of the anemia.

The three types of anemia based on red blood cell size are microcytic, normocytic, and macrocytic. The mean corpuscular volume (MCV) is a measure that indicates the average volume or size of a single red blood cell and is found within a complete blood count (CBC). Click each section below to review each anemia classification by size.

Microcytic Anemia

- MCV is below the normal range or less than 80 fL.
- Indicates smaller-than-normal red blood cells.
- Common causes of microcytic anemia include iron deficiency or

thalassemia. Normocytic Anemia

- MCV falls within the normal range of 80 to 100 fL.
- Indicates normal-size red blood cells.
- Causes of normocytic anemia may include acute blood loss, chronic diseases (such as cancer), kidney failure, hereditary spherocytosis, G6PD deficiency, and paroxysmal nocturnal hemoglobinuria.

Macrocytic Anemia

- MCV is above the normal range or greater than 100 fL.
- Indicates larger-than-normal red blood cells.
- Common causes of macrocytic anemia include vitamin B-12 deficiency or folate deficiency.

Anemias are classified by the size and color of the red blood cells. Size is measured by the mean corpuscular volume (MCV), and a normal value is 80 to 100 fL. The size is classified as microcytic (below the normal range), normocytic (within the normal range), or macrocytic (above the normal range). The color, or concentration of the hemoglobin is measured by the mean corpuscular hemoglobin concentration (MCHC), and a normal value is 32 g/dL to 36 g/dL. The color can be classified as hypochromic (below the normal range), normochromic (within the normal range), or macrochromic (above the normal range).

ANEMIA CLASSIFICATION: COLOR

The three types of anemia based on red blood cell color are hypochromic, normochromic, and hyperchromic. The mean corpuscular hemoglobin concentration (MCHC) is a measure of the concentration of hemoglobin in a red blood cell and is found within a complete blood count (CBC).

Hypochromic Anemia

- MCHC is below the normal range or less than 32 g/dL.
- Red blood cells appear pale in color.

Normochromic Anemia

- MCHC is within the normal range of 32 g/dL to 36 g/dL.
- Red blood cells appear neither pale nor dark.

Hyperchromic Anemia

- MCHC is higher than the normal range or higher than 36 g/dL.
- Red blood cells appear darker or more red than typical cells.

Anemias can be classified according to the color of the RBCs:

- Hypochromic Anemia describes RBCs with less hemoglobin than normal. As a result, the RBCs appear pale in color (MCHC is low).
- Normochromic Anemia describes RBCs that have a normal amount of hemoglobin. As a result, the RBCs appear neither pale nor dark (MCHC is normal).
- Hyperchromic Anemia describes RBCs with more hemoglobin than normal. As a result, the RBCs appear a darker hue or more red than normal cells (MCHC is high).

ANEMIA MANIFESTATIONS

Anemia can mimic the signs and symptoms of other serious conditions and can vary depending on the degree of reduction in the blood's oxygen-carrying capacity and the body's ability to compensate. A reduction in red blood cells and hemoglobin results in hypoxemia and tissue hypoxia.

Clinical manifestations of anemia include weakness, fatigue, pallor, muscle pain, increased respiratory rate, exertional dyspnea, dizziness, and fainting. Hypoxemia and tissue hypoxia trigger cardiovascular, respiratory, and renal compensatory mechanisms.

Compensatory Mechanisms:

Cardiovascular

- Increased heart rate
- Increased stroke volume
- Cardiac murmurs
- Cardiac failure
- Capillary dilation
- Increased oxygen demands on the heart
- Angina
- Increased erythropoietin

Respiratory

- Increased rate of breathing
- Increased depth of breathing
- Increased release of oxygen from the hemoglobin

Renal

- Increased renin-aldosterone response
- Increased salt and water retention
- Increased extracellular fluid

ANEMIA DIAGNOSING AND TREATMENT

Diagnosing anemia involves a comprehensive evaluation to determine the type, severity, and underlying causes of the condition. A thorough health history and physical are necessary to identify potential causes of anemia such as chronic diseases, gastrointestinal bleeding, or nutritional deficiencies. Key diagnostic tests may include a complete blood count (CBC), a peripheral blood smear examination to determine the size, shape, and color of the blood cells, or levels such as iron, vitamin B-12, folate, or erythropoietin.

Treatment for anemia can include diet changes, supplementation of iron, folate, or vitamin B-12, blood transfusions, or bone marrow stimulation.

Treatment for Anemia Caused by Iron Deficiency

For clients with anemia caused by iron deficiency, educate them about dietary sources of iron such as meat, grains, fruits, and vegetables. For clients taking iron supplements, they should be aware that certain foods or medications can reduce the absorption of iron supplements such as tea, coffee, calcium supplements, milk, and antacids. Side effects of iron supplements include a metallic taste, nausea, vomiting, constipation, and dark-colored stools. Clients whose gastrointestinal tract cannot absorb an adequate amount of iron from pills may require intravenous injection.

Complete Blood Count

Red Blood Cells (RBC): The number of erythrocytes in 1 cubic mm of whole blood. Normal for men is 4.7–6.1 mcL; Normal for women is 4.5–5.2 mcL.

Hematocrit (Hct): The volume of cells as a percentage of the total volume of cells and plasma in whole blood. Normal for men is 42–45%; Normal for women is 37–48%.

Mean Cell Volume (MCV): This measures the average size of the RBC. Normal is 80–100 fL.

Mean Corpuscular Hemoglobin Concentration (MCHC): Average concentration of hemoglobin per erythrocyte. Normal is 32–36%.

Hemoglobin (Hb): The oxygen-carrying pigment of red cells. Normal for men is 13.5–17.5 g/dL. Normal for women is 12.0–15.5 g/dL.

Reticulocyte: Immature RBCs. Used to assess bone marrow function. Normal in adults is approximately 3%.

Mean Corpuscular Hemoglobin (MCH): Average weight of hemoglobin per red cell. Normal is 27–33 pg.

Red Cell Distribution Width (RDW): This index is a quantitative estimate of the uniformity of individual cell size. Normal is 11.5–14.5%

RISK FACTORS

Heavy menstrual bleeding can lead to iron deficiency anemia. Chronic blood loss during menstruation may deplete iron stores over time, affecting hemoglobin levels. A vegetarian diet, especially if not well-balanced, can be associated with nutritional deficiencies, including iron and vitamin B-12. Iron deficiency anemia is a common consequence of inadequate dietary iron intake, and vitamin B-12 deficiency can contribute to a different type of anemia (pernicious anemia). Ulcerative colitis, an inflammatory bowel disease, can contribute to anemia. Inflammation in the gastrointestinal tract may interfere with nutrient absorption, leading to deficiencies in iron and other essential nutrients, contributing to anemia. Ulcerative colitis can also cause increased erythrocyte destruction or blood loss from an exacerbation.

While physical activity is essential for overall health, it is not a primary cause of anemia. The focus should be on factors that contribute to nutritional deficiencies or chronic blood loss. Anemia can be caused by vitamin B-12 deficiency, so taking vitamin B-12 supplements would not be a risk factor for anemia.

Comparing the pre- and post-surgical hemoglobin and hematocrit indicates potential blood loss during the surgery, resulting in anemia. Signs of anemia include fatigue, pallor, dyspnea, tachypnea, and tachycardia.

Hypertension, bradypnea, and edema are not signs of anemia.

If the client is receiving ferrous sulfate to replenish iron levels to promote red blood cell production. Calcium carbonate prevents absorption of iron and should be held at this time.

Vitamin C improves the absorption of iron so it should be continued. Acetaminophen and birth control should not have any effect on other medications or the client's condition.

Clients with iron-deficiency anemia must increase their intake of iron by eating foods like dark, leafy green vegetables, nuts, and dried fruit. Iron supplements may also be needed to replenish iron stores.

Vitamin C helps the absorption of non-heme iron. The most frequent side effects of iron supplementation include nausea and constipation, not diarrhea. Vegetarians must be purposeful about food choices to ensure an adequate intake of iron.

INTRODUCTION TO MICROCYTIC ANEMIAS

Microcytic anemias are a group of blood disorders characterized by smaller-than-normal red blood cells, typically measured by a reduced mean corpuscular volume (MCV). The most common causes of microcytic anemias include iron deficiency, thalassemias, and certain chronic diseases, each affecting the synthesis or availability of hemoglobin within red blood cells.

Microcytic anemia (MCV less than 80)

Small red blood cells are produced and lack oxygen-carrying capacity.
Causes: Iron deficiency anemia or thalassemia

Normocytic anemia (MCV between 80 to 100)

Red blood cells are lost or destroyed.
Causes: Bleeding or kidney failure

Macrocytic anemia (MCV greater than 100)

Large red blood cells are produced and lack oxygen-carrying capacity.
Causes: Folate or vitamin B-12 deficiency

Serum ferritin is a protein that stores iron and releases it in a controlled fashion. The serum ferritin test measures the concentration of ferritin in the blood and is a key indicator of the body's iron stores. Low serum ferritin levels may suggest depleted iron stores, indicative of iron deficiency.

Serum iron measures the amount of iron circulating in the bloodstream. Transferrin saturation represents the percentage of iron-binding sites on transferrin that are occupied by iron. The total iron-binding capacity measures the maximum amount of iron that can be carried in the blood. The hemoglobin level is a measurement of the blood's oxygen-carrying capacity. The hematocrit is a measure of the volume percentage of red blood cells in the total blood volume.

By assessing these laboratory results, the nurse practitioner can gain valuable insights into the client's iron status, whether it indicates a deficiency, normal levels, or potential iron overload. Interpretation of the laboratory results should be done in conjunction with the client's clinical history and presentation for a comprehensive understanding of their iron status.

Risk Factors

Donating blood every 3 months because regular blood donation can contribute to a gradual depletion of iron stores. The NP should consider counseling and monitoring iron levels in individuals engaged in frequent blood donation to mitigate this risk. Pregnant or breastfeeding clients have increased iron requirements. Clients with gastrointestinal ulcers are at risk of bleeding. Clients with chronic conditions such as congestive heart failure may have decreased absorption of iron or may take medications such as anticoagulants.

The NP should anticipate that a client with beta thalassemia major will require blood transfusions to address the anemia and chelation therapy to remove excess iron built up from blood transfusions.

Clients with beta thalassemia minor may be asymptomatic or have mild symptoms. Clients with iron deficiency anemia may have symptoms like pica and spoon-shaped fingernails.

PATHOPHYSIOLOGY OF MICROCYTIC ANEMIAS

Microcytic anemias are characterized by smaller-than-normal erythrocytes and decreased hemoglobin levels and are caused by a reduction in the body's iron stores and a hemoglobin synthesis deficiency. The most common cause of microcytic anemia is iron deficiency, but it can also be caused by chronic diseases, thalassemia, sideroblastic anemia, and hemoglobinopathies.

Normal development of erythrocytes is dependent upon an adequate supply of essential nutrients, including iron, copper, and vitamin B-12. These nutrients play crucial roles in the synthesis of hemoglobin, as the protein responsible for carrying oxygen in red blood cells. The liver functions as a vital storage reservoir for these nutrients, storing iron as ferritin, and retaining copper and vitamin B-12 during times of excess intake. When there is an insufficient supply of these nutrients, the production of erythrocytes may slow down, potentially causing microcytic anemia.

The Structure of Hemoglobin:

- Iron
- Heme
- Polypeptide chain
- Oxygen molecules