CHAPTER 9 – CARDIOVASCULAR SYSTEM

OBJECTIVES

On completion of this chapter, you will be able to:

- Describe the cardiovascular system.
- Describe and state the functions of arteries, veins, and capillaries.
- Describe cardiovascular differences of the child and the older adult.
- Identify the commonly used pulse checkpoints of the body.
- Describe blood pressure.
- Analyze, build, spell, and pronounce medical words.
- Comprehend the drugs highlighted in this chapter.
- Describe the diagnostic and laboratory tests related to the cardiovascular system.
- Identify and define selected abbreviations.
- Describe each of the conditions presented in the Pathology Spotlights.
- Review the Pathology Checkpoint.
- Complete the Study and Review section and the Chart Note Analysis.

OUTLINE

I. Anatomy and Physiology Overview

Through the cardiovascular system, blood is circulated to all parts of the body by the action of the heart. This process provides the body’s cells oxygen and nutritive elements and removes waste materials and carbon dioxide.

A. Heart (Fig. 9–1, p. 232) – is a four-chambered, hollow muscular pump that circulates blood throughout the cardiovascular system and the heart is the center of the cardiovascular system from which the various blood vessels originate and later return. The heart has three layers or linings:

- **Endocardium** – the inner lining of the heart.
- **Myocardium** – the muscular, middle layer of the heart.
- **Pericardium** – the outer, membranous sac surrounding the heart.

1. **Chambers of the Heart** – the heart acts as a double pump and is divided into the right and left heart by a partition called the septum. Each side contains an upper and lower chamber:

   a. **Atria** – the upper chambers separated by the interatrial septum. The atrium receives blood from various parts of the body.

   - **Right Atrium (RA)** – located at the right upper portion, it is a thin-walled space that receives blood from all body parts except the lungs. Two large veins, *superior* and *inferior vena cava*, bring the blood to the right atrium.
• **Left Atrium (LA)** – located at the left upper portion, it receives blood rich in oxygen as it returns from the lungs via the right and left pulmonary veins.

b. **Ventricles** – the lower chambers separated by an interventricular septum. The ventricles pump blood to body parts.

  • **Right Ventricle (RV)** – located at the right lower portion, it receives blood from the right atrium through the atrioventricular (AV) valve and pumps it through a semilunar valve to the lungs.
  
  • **Left Ventricle (LV)** – located at the left lower portion, it receives blood from the left atrium through an atrioventricular (AV) valve and pumps it through a semilunar valve to a large artery known as the aorta and from there to all parts of the body except the lungs.

2. **Heart Valves** (Fig. 9-2, p. 234) – the valves are located at the entrance and exit of each ventricle. They are as follows:
   
a. **Tricuspid Valve** or **Right Atrioventricular** – guards the opening between the right atrium and right ventricle. The tricuspid valve allows the flow of blood into the ventricle and prevents its return to the right atrium

  b. **Pulmonary Semilunar Valve** – the exit point for blood leaving the right ventricle is located between the right ventricle and the pulmonary artery. It allows blood to flow from the right ventricle through the pulmonary artery to the lungs.

  c. **Bicuspid or Mitral Valve** – also known as the left atrioventricular valve, it is located between the left atrium and left ventricle. It allows blood to flow to the left ventricle and closes to prevent its return to the left atrium.

  d. **Aortic Semilunar Valve** – the exit point for blood leaving the left ventricle is located between the left ventricle and the aorta. It allows blood to flow into the aorta and prevents its return to the ventricle.

3. **Vascular System of the Heart** (Fig. 9–3, p. 235) – the heart has its own vascular system because of the membranous endocardium and thickness of the myocardium. The coronary arteries supply the heart with blood and the coronary veins, draining into the coronary sinus, collect the blood and return it to the right atrium.

B. **Flow of Blood** (Fig. 9–4, p. 236) – blood flows through the heart, to the lungs, back to the heart, and to various parts of the body as follows:

  • Blood from the superior and inferior vena cava enters the right atrium.
• Blood passes through the tricuspid valve into the right ventricle.
• Right ventricle pumps blood through the pulmonary semilunar valve into the left and right pulmonary arteries.
• Pulmonary arteries carry blood to the lungs where the blood gives up waste and takes on oxygen as it passes through capillaries (microscopic blood vessels with thin walls that allow the passage of oxygen and nutrients to the body and lets the blood pick up waste and carbon dioxide) into veins.
• Blood leaves the lungs through the left and right pulmonary veins carrying it to the left atrium.
• The oxygenated blood passes through the bicuspid valve into the left ventricle.
• The blood is pumped through the aortic semilunar valve and into the aorta.
• The aorta (a large artery) supplies a branching system of smaller arteries that connect to tiny capillaries throughout the body.

1. Heartbeat (Fig. 9–5, p.237) – is controlled by the autonomic nervous system and is generated by specialized neuromuscular tissue of the heart. These tissues include:

   a. Sinoatrial Node (SA Node) – also known as the pacemaker of the heart, is located in the upper chamber of the right atrium, just below the opening of the superior vena cava. It consists of a dense network of Purkinje fibers (atypical muscle fibers) considered to be the source of the impulses initiating the heartbeat. Electrical impulses discharged by the SA node are distributed to the right and left atria and cause them to contract.

   b. Atrioventricular Node (AV Node) – located beneath the endocardium of the right atrium, the AV node transmits electrical impulses to the bundle of His.

   c. Atrioventricular Bundle (Bundle of His) – extends from the AV node into the intraventricular septum, where it divides into two branches within the two ventricles. The Purkinje system include the bundle of His and the peripheral fibers, which end in the ventricular muscles, where the excitation of muscle is initiated, causing contraction. The average heartbeat (pulse) is between 60 and 100 beats per minute for the average adult. The heart rate may be affected by emotions, smoking, disease, body size, age, stress, the environment, and many other factors.

2. Electrocardiogram (ECG or EKG) (Fig. 9–6, p. 238) – record of the electrical activity of the heart, which provides valuable information in the diagnosing of cardiac abnormalities. A standard ECG consists of 12 different leads.
C. **Arteries (Fig. 9–7, p. 239)** – consist of a branching system of vessels that transport blood from the right and left ventricles of the heart to all body parts. In a normal state, they are elastic tubes that recoil and carry blood in pulsating waves. All arteries have a pulse, which reflects the rhythmical beating of the heart. Following is a list of points commonly used to check the rate, rhythm, and condition of arterial walls (Fig. 9–8, p. 240):

1. **Radial** – located on the radial side (thumb side) of the wrist and is most commonly used for taking pulse.
2. **Brachial** – located in the antecubital space of the elbow and is the most common site to check blood pressure.
3. **Carotid** – located in the neck and is readily accessible during an emergency.
4. **Temporal** – located at the temple area of the head and is used to control bleeding from the head and scalp and to monitor circulation.
5. **Femoral** – located in the groin and used to monitor circulation.
6. **Popliteal** – located behind the knee and used to monitor circulation.
7. **Dorsalis Pedis** – located on the upper surface of the foot and used to monitor lower limb circulation.

D. **Blood Pressure** – the pressure exerted by the blood on the wall of the vessels. The term most commonly refers to the pressure exerted in large arteries at the peak of the pulse wave.

- **Sphygmomanometer (Fig. 9–9, p. 241)** – instrument used to measure blood pressure, which is measured in millimeters of mercury (mmHg) as observed on a graduated scale.
- **Stethoscope** – an instrument used to listen to the sounds of the heart, lungs, and other internal organs.

1. **Pulse Pressure** – difference between the systolic and diastolic readings. The reading indicates the tone of the arterial walls.

E. **Veins (Fig. 9–10, p. 242)** – vessels that transport blood from the peripheral tissue and from the lungs to the heart. In a normal state veins have thin walls and valves that prevent the backflow of blood. These are the vessels used when blood is removed for analysis in a process known as venipuncture.

F. **Capillaries** – microscopic blood vessels with single-celled walls that connect **arterioles** (small arteries) with **venules** (small veins). Blood passing through capillaries, gives up oxygen and nutrients carried to this point by arteries and picks up waste and carbon dioxide as it enters veins. The extremely thin walls of the capillaries facilitate passage of life-sustaining fluids containing oxygen and nutrients to cell bodies and the removal of accumulated waste and carbon dioxide.
II. Life Span Considerations

A. The Child – development of the fetal heart is usually completed during the first two months of intrauterine life. It is completely formed and functioning by 10 weeks; therefore most congenital heart defects occur before this time. At 16 weeks fetal heart tones can be heard with a fetoscope. More than 50 congenital heart defects have been recognized by pediatric cardiologist. Oxygen is received by the fetus through fetal circulation and discontinues when the umbilicus is clamped. Pulse, blood pressure, and respiration will vary according to age.

B. The Older Adult – current evidence indicates that cardiac changes once attributed to the aging process can be minimized by modifying lifestyle and personal habits, such as following a low-sodium, low-fat diet, not smoking, drinking in moderation, managing stress, and exercising regularly. In some older adults, however, the heart must work harder to pump blood because of:

1. **Arteriosclerosis** – hardening of the arteries.
2. **Atherosclerosis** – buildup of fatty plaque (cholesterol deposits and triglycerides) in arterial walls. **Arteriosclerotic heart disease (AHD)** occurs when the arterial vessels are marked by thickening, hardening, and loss of elasticity in the arterial walls.
3. **Heart Failure (HF)** (Figs. 9–11 and 9–12, pp. 244, 245) – the inability if the ventricles to pump enough blood to meet the needs of the body
   a. **Left-sided, Left Ventricular (LV) Heart Failure, or Congestive Heart Failure (CHF)** – if the left ventricle loses its ability to contract normally (systolic failure), the heart can’t pump with enough force to push sufficient blood into circulation. If the ventricle loses its ability to relax normally (diastolic failure) because the muscle is thick, the heart can’t properly fill with blood during the resting period between each beat. This is important because drug treatment for each type of failure is different. This left-sided failure leads to pulmonary edema (buildup of fluid in the lungs), which causes dyspnea and shortness of breath.
   b. **Right-sided or Right Ventricular (RV) Heart Failure** – occurs because of left-sided failure. When the left ventricle fails, increased fluid pressure is, in effect, transferred back through the lungs, ultimately damaging the heart’s right side. Right-sided failure is a result of a buildup of blood flowing into the right side of the heart, which causes edema of the ankles, distention of neck veins, and enlargement of the spleen and/or liver.
III. Building Your Medical Vocabulary
A. Medical Words and Definitions – this section provides the foundation for learning medical terminology. Medical words can be made up of four types of word parts:
1. Prefix (P)
2. Root (R)
3. Combining Forms (CF)
4. Suffixes (S)
By connecting various word parts in an organized sequence, thousands of words can be built and learned. In the text, the word list is alphabetized so one can see the variety of meanings created when common prefixes and suffixes are repeatedly applied to certain word roots and/or combining forms. Words shown in pink are additional words related to the content of this chapter that have not been divided into word parts. Definitions identified with an asterisk icon (*) indicate terms that are covered in the Pathology Spotlights section of the chapter.

IV. Drug Highlights
A. Digitalis Drugs – strengthen the heart muscle, increase the force and velocity of myocardial systolic contraction, slow the heart rate, and decrease conduction velocity through the AV node. These drugs are used to treat CHF, atrial fibrillation, atrial flutter, paroxysmal atrial tachycardia. Toxicity can occur with usage. The most common early symptoms of digitalis toxicity are anorexia, nausea, vomiting, and arrhythmias.
B. Antiarrhythmic Agents – used to treat cardiac arrhythmias (irregular heart rhythms).
C. Vasopressors – cause contraction of the muscles associated with capillaries and arteries, thereby narrowing the space through which the blood circulates. This narrowing results in the elevation of blood pressure; used to treat patients suffering from shock.
D. Vasodilators – cause relaxation of blood vessels and lower blood pressure. Coronary vasodilators are used to treat angina pectoris.
E. Antihypertensive Agents – used to treat hypertension.
F. Antihyperlipidemic Agents – used to lower abnormally high blood levels of lipids when other treatment regimens fail.
G. Antiplatelet Drugs – help reduce the occurrence of and death from vascular events such as heart attacks and strokes.
H. Thrombolytic Agents – also known as tissue plasminogen activator (tPA, TPA), act to dissolve an existing thrombus when administered soon after its occurrence. These agents dissolve the clot, reopen the artery, restore blood flow to the heart, and prevent further damage to the myocardium thus reducing the chance of dying after a myocardial infarction by 50%. Bleeding is the most common complication encountered during thrombolytic therapy.
V. Diagnostic and Lab Tests

A. **Angiography** – x-ray recording of a blood vessel after the injection of a radiopaque substance; used to determine the condition of organs, tissues, or blood vessel being studied.

B. **Cardiac Catheterization** (Fig. 9–33, p. 264) – diagnosis of heart disorder whereby a tiny catheter is inserted into an artery and manipulated to the heart. Dye is then pumped through the catheter, enabling the physician to locate by x-ray any blockages in the arteries supplying the heart.

C. **Cardiac Enzymes** – blood test performed to determine cardiac damage in an acute myocardial infarction (AMI).
   1. **Alanine Aminotransferase Test (ALT)** – blood test to check the levels of this enzyme, which is released in higher levels by a damaged liver. Levels begin to rise 6 to 10 hours after a MI and peak at 24 to 28 hours.
   2. **Aspartate Aminotransferase Test (AST)** – blood test to check the levels of this enzyme, which is released in high levels as a result of body tissue or organ damage. After severe damage, levels begin to rise 6 to 10 hours and peak at about 24 to 48 hours.
   3. **Creatine Phosphokinase Test (CPK)** – measures the levels of creatine in the blood following a heart attack; used to detect the area of muscle damage.
   4. **Creatine Kinase (CK)** – levels may be 5 to 8 times the normal level.
   5. **Creatine Kinase Isoenzymes** – used to indicate area of damage; CK-MB heart muscle, CK-MM skeletal muscle, CK-BB brain.

D. **Cholesterol** – blood test to determine the level of cholesterol in the serum. Elevated levels may indicate an increased risk of coronary heart disease. Any level greater than 200 mg/dL is considered too high for good heart health.

E. **Echocardiography (ECHO)** – used to analyze the size, shape, and movement of structures inside the heart. Usually two echoes are taken – one with the heart at rest and another with the heart under stress. Comparison of the two images helps pinpoint abnormal valves or areas that are not receiving enough blood.

F. **Holter Monitor** – a method of recording a patient’s ECG for 24 hours. The device is portable and small enough to be worn by the patient during normal activities.

G. **Intracardiac Electrophysiology Study (EPS)** – invasive cardiac procedure that involves the placement of catheter-guided electrodes within the heart to evaluate and map the electrical conduction of cardiac arrhythmias.

H. **Lactic Dehydrogenase (LDH)** – intracellular enzyme present in nearly all metabolizing cells, with the highest concentration in the heart, skeletal muscles, RBCs, liver, kidney, lungs, and brain. Used for diagnosing acute myocardial infarction with a high serum level occurring 12 to 24 hours after cardiac injury.
I. **Lipid Profile** – series of blood test including cholesterol, high density lipoproteins, low density lipoproteins and triglycerides. Used to determine levels of lipids and to assess risk factors of coronary heart disease.

J. **Magnetic Resonance Imaging (MRI)** – use of a magnet that sets the nuclei of atoms in the heart cells vibrating. The oscillating atoms emit radio signals, which are converted by a computer into either still or moving 3-D images. The scan can reveal plaque-filled coronary arteries and the layer of fat that envelopes most hearts. MRI is also ideal method for scanning children with congenital heart problems. Patients with pacemakers, stents, or other metal implants cannot have a MRI. MRI cannot pick up calcium deposits, which could signal narrow vessels.

K. **Stress Test (Exercise Test, Exercise Stress Test, or Treadmill Test)** – method of evaluating cardiac fitness. The ECG is monitored while the patient is subjected to increasing levels of work using a treadmill or ergometer. It is a common test for diagnosing coronary artery disease, especially in patients who have symptoms of heart disease. The test helps doctors assess blood flow through coronary arteries in response to exercise at various lengths of time on a treadmill. A stress test may include use of electrocardiography, echocardiography, and injected radioactive substances.

L. **Thallium-201 Stress Test** – x-ray study that follows the path of radioactive potassium carried by the blood into heart muscle. Damaged or dead muscle can be defined, as can the extent of narrowing in an artery.

M. **Triglycerides** – blood test to determine the level of triglycerides in the serum. Elevated levels may indicate an increased risk of coronary heart disease and diabetes mellitus.

N. **Ultrasonography** – test used to visualize an organ or tissue by using high-frequency sound waves. Used as a screening or diagnostic tool to determine abnormalities of the aorta, arteries, veins and the heart.

O. **Ultrafast CT Scan** – used to diagnose heart disease. Ultrafast CT can take multiple images of the heart within the time of a single heartbeat, thus providing more detail about the heart’s function and structures, while decreasing the amount of time required for the study. Because it can detect very small amounts of calcium within the heart and the coronary arteries, which can block off one or more coronary arteries, it is being used as a means to diagnose early coronary disease.

VI. **Abbreviations (p. 266)**

VII **Pathology Spotlights**

A. **Coronary Heart Disease (CHD) (Figs. 9–34 and 9–35, pp. 267, 268)** – also referred to as **Coronary Artery Disease (CAD)**, CHD is the most common form of heart disease and the leading cause of death in the United States for men and women. It refers to the narrowing of coronary arteries that supply blood to the heart. It is a progressive disease that can lead to MI and sudden death. Symptoms include:
- **Angina** or chest pain.
- Chest pain that radiates to the neck, jaw, or left arm.
- Shortness of breath signifying heart failure.

Coronary heart disease is the leading cause of death in the United States. Conditions that lead to CHD include:

1. **Atherosclerosis** – the main cause of CHD. As the coronary arteries narrow, the blood to the heart can decrease or stop. Blockage can occur in one or more arteries.
2. **Stable Angina** – results from small blockages and occurs during exercise or other activities when the heart has an increased need for oxygen.
3. **Unstable Angina** – results from large blockages and occurs with little or no activity. In this case, the flow of blood to the heart is so limited that the person cannot do daily task without bring on an angina attack.

### B. Peripheral Artery Disease (PAD) – a condition in which fatty deposits build up in the inner linings of the artery walls. The blockages restrict blood circulation, mainly in arteries leading to the kidneys, stomach, arms, legs, and feet. Symptoms include:

- **Claudication** – dull, cramping pain in the hips, thighs, calves, or buttocks.
- Numbness or tingling in the leg, foot, or toes.
- Impotence.
- **Sores** or infections that do not heal.
- Weakness in legs or arms.

Techniques used to diagnose PAD include a medical history, physical exam, ultrasound, x-ray angiography, and magnetic resonance imaging (MRI). Treatment involves lifestyle changes, medications, or both, angioplasty with stent placement or SilverHawk™ Plaque Excision System (a system that includes a low-profile catheter and a palm-sized drive unit, which removes significant amounts of atherosclerotic tissue from long, diffusely diseased lesions).

Untreated PAD can result in **critical limb ischemia (CLI)**, which occurs when the oxygenated blood being delivered to the leg is not adequate to keep the tissue alive.

### C. Dysrhythmia or Arrhythmia – abnormality of the rhythm or rate of the heartbeat. The dysrhythmia is caused by a disturbance of the normal electrical activity within the heart. There are two main groups:

1. **Tachycardias** – rapid heartbeat of over 100 beats/min.
2. **Bradycardias** – slow heartbeat of less than 60 beats/min.

The symptoms of dysrhythmia can include:

- Dizziness or light-headedness
- Palpitations
- Shortness of breath
• Fatigue
• Weakness
• Angina
• Fainting

Most dysrhythmias are caused by heart disease, including CHD and disease of the heart valves, from infections such as endocarditis, and heart failure.

Dysrhythmias can be life threatening if they cause a severe decrease in the pumping function of the heart. Cardioversion is the process of using an electrical shock to the heart to restore its rhythm to a normal pattern. This electrical energy can be delivered externally through electrodes placed on the chest or directly to the heart by placing paddles on the heart during open heart surgery. This action is synchronized to the ECG and is delivered during critical parts of electrical sequence. It stops arrhythmias resulting from single or multiple reentry circuits in the atria or ventricles, such as:

• Atrial flutter
• Atrial fibrillation
• Atrioventricular nodal reentrant tachycardia
• Atrioventricular reentrant tachycardia
• Monomorphic ventricular tachycardia

Arrhythmias that arise from multiple reentry circuits in the ventricles, specifically ventricular fibrillation, are terminated by a technique called defibrillation, which is the nonsynchronized delivery of an electric shock.

D. Hypertension (HTN) (Fig. 9–36, p. 271) – blood pressure (BP) reading higher than normal. With hypertension, the blood vessels become tight, constrict, and cause the blood to press on the vessel walls with extra force. When this force exceeds a certain level and remains there, a person has high blood pressure (HBP). Hypertension is known as the silent killer because often there are no symptoms associated with the disease. If left untreated, it can lead to kidney failure, stroke, heart attack, peripheral artery disease and eye damage. There is no cure for hypertension but it can be controlled by:

• Taking blood pressure medications as prescribed.
• Seeing a physician on a regular basis.
• Establishing healthy eating habits.
• Exercising.
• Avoiding stress.
• Making lifestyle changes.

Various risk factors can contribute to the development of hypertension and it is important to know these factors (Table 9–2, p. 272).

E. Prehypertension – individuals aged 18 years and over with blood pressure ranging from 120/80 to 139/89 mm Hg belong to a new category designated as prehypertension, a high risk precursor to hypertension,
According to the Joint National Committee (JNC) Seventh Report. According to this report, adults at the upper end of prehypertension are twice as likely to proceed to hypertension as those with lower blood pressure levels. Lifestyle and dietary modifications are critical in the prevention of high blood pressure.

F. **Heart Attack (Myocardial Infarction) (MI)** – occurs when the blood supply to part of the heart muscle (myocardium) is severely reduced or stopped, because of blocked coronary arteries. The blockage is usually from the buildup of plaque (deposits of fatlike substances) due to atherosclerosis. The plaque can eventually tear or rupture, triggering a blood clot that blocks the artery and leads to a heart attack. Such an event is known as a **coronary thrombosis** or **coronary occlusion**. The most common symptom of a heart attack is chest pain or **angina**. The pain is often described as a feeling of crushing, pressure, fullness, heaviness, or aching in the center of the chest. These symptoms may extend into the neck, the jaw, and down the left arm. Angina is often associated with excessive sweating, feelings of apprehension, nausea, shortness of breath, and weakness. Some heart attacks are sudden and intense, but most start slowly with mild pain or discomfort. The warning signs of a heart attack as listed by The American Heart Association are:

1. Pressure, fullness, squeezing pain in the center of the chest that lasts 2 minutes or longer.
2. Pain that spreads to the shoulders, neck, or arms.
3. Dizziness, fainting, sweating, nausea, or shortness of breath.

V. **Pathology Checkpoint**

VI. **Study and Review (pp. 274–280)**

VII. **Practical Application: SOAP: Chart Note Analysis**