Chapter 18

Anatomy of the Blood Vessels and Special Circulations

Objectives

- 1. Describe the pulmonary and systemic circulations.
- 2. Describe the structure and function of arteries, capillaries, and veins, including the following:
- • List the three layers of tissue found in arteries and veins.
- • Explain the functions of conductance, resistance, exchange, and capacitance vessels.
- 3. List the major arteries of the systemic circulation that are branches of the ascending aorta, aortic arch, and descending aorta.
- 4. List the major veins of the systemic circulation.
- 5. Describe the following special circulations: blood supply to the head and brain, hepatic circulation, and fetal circulation.
- 6. Explain pulse and its use as an assessment tool.

Circles, Circuits, and Circulations

- The blood vessels are a series of connected hollow tubes that begin and end in the heart
- The blood vessels form a path through the body, much like the system of highways and roads that enables us to travel from place to place
- Figure 18.1 page 341
- The heart and blood vessels form a circuit
- The heart pumps blood into the large artery. The blood flows through a series of blood vessels back to the heart.
- Moving from heart to blood vessels to heart, the blood forms a circuit, or circulation. This arrangement ensures a continuous one-way movement of blood
- The two main circulations are the pulmonary circulation and the systemic circulation
- The pulmonary circulation carries blood from the right ventricle of the heart to the lungs and back to the left atrium of the heart ---The pulmonary circulation transports unoxygenated blood to the lungs, where oxygen is loaded and carbon dioxide is unloaded. Oxygenated blood then returns to the left side of the heart to be pumped into the systemic circulation.
- The systemic circulation is the larger circulation; it provides the blood supply to the rest of the body. The systemic circulation carries oxygen and other nutrients to the cells and picks up carbon dioxide and other waste.

Naming the Blood Vessels

- The blood vessels are the body's highways; they are anatomically classified as arteries, capillaries, and veins (Table 18.1) page 343
- Arteries are blood vessels that carry blood away from the heart. The large arteries repeatedly branch into smaller and smaller arteries as they are distributed throughout the entire body. As they branch, the arteries become much more numerous but smaller in diameter. The smallest arteries are called arterioles. Most of the arteries are color coded red because they carry oxygenated blood.
- The capillaries are the smallest and most numerous of all the blood vessels. They connect the arterioles with the venules. Because the body has so many of them, a capillary is close to every cell in the body. This arrangement provides every cell with a continuous supply of oxygen and other nutrients. At the capillary level, the blood gives up its oxygen to the tissues; the unoxygenated blood leaving the tissues is therefore bluish.
- Veins are blood vessels that carry blood back to the heart. Blood flows from the capillaries into the veins. The smallest veins are called venules. The small venules converge to form fewer but larger veins. The largest veins empty the blood into the right atrium of the heart. Most of the veins are color coded blue because they carry unoxygenated blood.

Blood Vessel Walls: The Layered Look

- Figure 18.2 page 342
- Except for the capillaries, the blood vessels are composed of three layers (or tunics) of tissue
  - tunica intima, tunica media, and tunica adventitia.
    - Tunica intima. The tunica intima is the innermost layer, an endothelium. The endothelial lining forms a slick, shiny surface continuous with the endocardium, the inner lining of the heart. Blood flows easily and smoothly along this surface.
    - Tunica media. The tunica media is the middle layer. It is the thickest layer and is composed primarily of elastic tissue and smooth muscle; the thickness and composition vary according to the function of the blood vessel. The large arteries, for example, contain considerable elastic tissue so that they can stretch in response to the pumping of blood by the heart. The smallest of the arteries, the arterioles, are composed primarily of smooth muscle. The muscle allows the arterioles to contract and relax, thereby changing the diameter of the arteriole.
    - Tunica adventitia. The outer layer is called the tunica adventitia. Composed of tough connective tissue, its main function is to support and protect blood vessels.

Blood Vessels: What They do

- Arteries
  - The walls of the large arteries are thick, tough, and elastic because they must withstand the high pressure of the blood pumped from the ventricles.
  - Because the primary function of the large arteries is to conduct blood from the heart to the arterioles, the large arteries are called conductance vessels
- Arterioles
  - The arterioles are the smallest of the arteries --They are composed primarily of smooth muscle and spend most of their time contracting and relaxing. By changing their diameter, the arterioles affect resistance to the flow of blood.
  - A narrow (constricted) vessel offers an increased resistance to blood flow; a wider (dilated) vessel offers less resistance.
  - Because of their effect on resistance, the arterioles are called resistance vessels
- Capillaries
  - The capillaries have the thinnest walls of any of the blood vessels
  - The capillary wall is made up of a single layer of endothelium lying on a delicate basement membrane
  - The thin capillary wall enables water and dissolved substances, including oxygen, to move across the capillary wall from the blood into the tissue spaces, where they become available for use by the cells.
  - The capillary also allows waste from the metabolizing cell to diffuse from the tissue spaces into the capillaries for transport by the blood to the organs of excretion.
  - The capillaries are called exchange vessels because they allow for an exchange of nutrients and waste.

Blood Vessels: What They do

- Veins and Venules
  - The venule wall is slightly thicker than the capillary wall--As the venules converge to form larger veins, the walls become even thicker---The tunica media of the vein, however, is much thinner than the tunica media of the artery. This difference is appropriate because pressure in the veins is much less than the pressure in the arterial blood vessels.
  - In addition to thinner walls, the veins differ in another way; most veins contain one-way valves – they direct the flow of blood toward the heart.
  - While the valves facilitate the movement of venous blood toward the heart, the veins sometimes need some “outside” help. ---This is particularly true of the veins of the lower extremities. Although blood pressure is very high in the arterial circulation, it decreases to almost 0 mm Hg in the veins--- The pressure in the veins is so low, in fact, that it alone cannot return blood from the veins back to the heart
  - The “outside” help is the skeletal muscle pump
  - The large veins in the leg are surrounded by skeletal muscles. When the skeletal muscles are relaxed and blood flow slows, the valves close. As the skeletal muscles contract, they squeeze the large veins, thereby opening the valves and forcing blood toward the heart. This mechanism is called the skeletal muscle pump. The pump explains the beneficial effects of exercise for your patients. Exercise improves venous return of blood to the heart and prevents stagnation of blood and thrombosis (blood clot formation).
  - In addition to carrying blood back to the heart, the veins play another role. The veins store blood. ----about 70% of the total blood volume is found on the venous side of the circulation. Because the veins store blood, they are called capacitance vessels.
  - When this stored blood is needed, the veins constrict (venoconstriction) and move blood to the heart for circulation.
  - Sum It Up page 344

Major Arteries of the Systemic Circulation

- The major arteries of the systemic circulation include the aorta and the arteries arising from the aorta.
- Aorta
  - is the mother of all arteries
  - aorta originates in the heart's left ventricle, extends upward from the left ventricle, curves in an archlike fashion, and then descends through the thoracic and abdominopelvic cavities
  - aorta ends in the pelvic cavity, where it splits into two common iliac arteries
  - aorta is divided into segments, each named according to two systems
    - One system is the path that the aorta follows as it courses through the body--- In this system, the aorta is divided into the ascending aorta, the arch of the aorta, and the descending aorta.
    - In the second naming system, the aorta is named according to its location within the body cavities. Thus, we have the thoracic aorta and the abdominal aorta.

Branches of the Aorta

- Figure 18.5 page 346
- All systemic arteries are direct or indirect branches of the aorta
- In other words, the arteries arise directly from the aorta, or they arise from vessels that are themselves branches of the aorta
- The systemic arteries are described in the order in which they arise from the aorta
- Branches of Ascending Aorta
  - The ascending aorta arises from the left ventricle of the heart --It begins at the aortic semilunar valve and extends upward to the aortic arch
  - The coronary arteries are distributed throughout the heart and supply oxygenated blood to the myocardium
- Branches of the Aortic Arch
  - The aortic arch extends from the ascending aorta to the beginning of the descending aorta. The following three large arteries arise from the aortic arc
  - The brachiocephalic artery is a large artery on the right side of the body. --These arteries supply the right side of the head and neck and the arm and hand regions. (There is no left brachiocephalic artery.)
  - The left common carotid artery extends upward from the highest part of the aortic arch and supplies the left side of the head and neck. Note that the left common carotid artery arises directly from the aorta, whereas the right common carotid artery arises from the brachiocephalic artery.
  - The left and right subclavian arteries supply blood to the shoulders and upper arms. The right subclavian artery is an extension of the brachiocephalic artery while the left subclavian artery arises from the aortic arch. The subclavian arteries give rise to the vertebral arteries (supplies the brain) and also extend toward the shoulder as the axillary arteries; they then enter the arm as the brachial arteries. At the elbow the brachial artery divides into the ulnar and radial arteries, which supply the forearm. The distal radial artery comes close to the surface at the wrist and is the site where the radial pulse can be assessed. Extensions of the ulnar and radial arteries form arteries that supply the hand.

Branches of the Ascending & Descending Aorta Thoracic & Abdominal

- The thoracic aorta (ascending) is the upper portion of the descending aorta. It extends from the aortic arch to the diaphragm. Intercostal arteries arise from the aorta and supply the intercostal muscles between the ribs
- The abdominal aorta extends from the thoracic aorta to the lower abdomen. Branches of the abdominal aorta include the following:
  - The celiac trunk is a short artery that further divides into three smaller arteries: the gastric artery supplies the stomach, the splenic artery supplies the spleen, and the hepatic artery supplies the liver.
  - Two mesenteric are the superior and inferior segments. The superior mesenteric artery supplies blood to most of the small intestine and part of the large intestine. The other part of the large intestine receives its blood supply from the inferior mesenteric artery.
  - Two renal arteries supply blood to the right and left kidneys. Other branches of the abdominal aorta include the gonadal arteries and the lumbar arteries.
- The distal abdominal aorta splits into the right and left common iliac arteries.
- The common iliac arteries divide into the internal and external iliac arteries.
  - The internal iliac artery supplies the pelvic organs and external reproductive organs.
  - The external iliac artery provides most of the blood to the lower extremities.
  - The external iliac artery extends into the thigh as the femoral artery, becoming the popliteal artery, and then the anterior and posterior tibial arteries. The anterior tibial artery continues into the foot as the dorsalis pedis artery. Palpation of the dorsalis pedis pulse is used to assess blood flow in the foot.

Major Veins of the Systemic Circulation

- Superficial veins - can be seen
- Deep veins are located more deeply and usually run parallel to the arteries
- The names of the deep veins are the same as the names of the companion arteries
- Venae Cavae
    - The veins carry blood from all parts of the body to the venae cavae for delivery to the heart
    - The venae cavae are the main veins
    - They are divided into the superior vena cava (SVC) and the inferior vena cava (IVC)
    - Veins draining blood from the head, shoulders, and upper extremities empty into the SVC
    - Veins draining the lower part of the body empty into the IVC
    - The SVC and IVC empty into the right atrium
- Do You Know Page 348

Veins That Empty Into the Superior Vena Cava

- The SVC receives blood from the head, shoulder, and upper extremities
- Veins may drain directly or indirectly into the SVC
- Figure 186.6 page 349
  - The cephalic vein is a superficial vein that drains the lateral arm region and carries blood to the axillary vein toward the SVC.
  - The basilic vein is a superficial vein that drains the medial arm region. The cephalic and basilic veins receive unoxygenated blood from the ulnar and radial veins in the forearm. They are joined by the median cubital vein (anterior aspect of the elbow). Blood samples are often drawn from the median cubital vein.
  - The axillary vein receives blood from the blood vessels in the arm and delivers it to the subclavian vein. The subclavian vein receives blood from the axillary vein and from the jugular veins and delivers it to the brachiocephalic vein (→ SVC).
  - The jugular veins drain blood from the head and drain into the subclavian veins. The external jugular veins drain blood from the face, scalp, and neck. The internal jugular veins drain blood from the brain. The internal jugular vein, in fact, is the main vein that drains the brain. Because the jugular veins are so close to the heart (right atrium), the pressure in the jugular veins reflects the pressure of blood in the right side of the heart. A person in right-sided heart failure has a higher-than-normal pressure in the right heart. This is observed clinically as pulsating jugular veins and is referred to as jugular vein distention (JVD). As a clinician, you will be observing, measuring, and recording JVD.
  - The azygos vein is a single vein that drains the thorax and empties directly into the SVC.

Veins That Empty Into the Inferior Vena Cava

- The IVC returns blood to the heart from all regions of the body below the diaphragm
- Figure 18.6 page 349
  - The tibial veins drain the calf and foot regions. The posterior tibial vein drains into the popliteal vein (behind the knee) and then the femoral vein (in the thigh). The femoral vein enters the pelvis as the external iliac vein; it joins with the internal iliac vein and continues as the common iliac vein. The common iliac vein continues as the IVC.
  - The great saphenous veins are the longest veins in the body. They begin in the foot, ascend along the medial side, and merge with the femoral vein to become the external iliac vein. These veins receive drainage from the superficial veins of the leg and thigh region. The great saphenous veins also connect with the deep veins of the leg and thigh. Thus, blood can return from the lower extremities to the heart by several routes. The great saphenous veins are sometimes "borrowed" by cardiac surgeons. Portions of a vein are surgically removed and transplanted into the heart to bypass clogged coronary arteries.
  - The renal veins drain the right and left kidneys, emptying blood directly into the IVC.
  - The hepatic veins drain the liver, emptying blood directly into the upper IVC. Because the hepatic veins are so close to the heart, congestion of the right heart often causes congestion in the hepatic veins and liver.
- Do You know page 350
- Sum It Up page 350

Special Circulations

- Most organs receive oxygen-rich blood from a single large artery, whereas oxygen-poor blood is drained by large veins.
- Several organs have circulations that are arranged differently.
- These special circulations include the blood supply to the head and brain, the blood supply to the liver, and the arrangement of the blood vessels in the unborn child (fetal circulation).
- The brain requires a continuous supply of blood; even a few minutes without oxygen alters the level of consciousness and causes brain damage. To ensure a rich supply of blood, the head is supplied by two pairs of arteries: carotid arteries and vertebral arteries
- Do You Know page 350
- Branches of the basilar artery connect with branches of the internal carotid arteries forming a circle of arteries at the base of the brain. This circular arrangement of arteries is called the circle of Willis --Arising from the circle of Willis are many arteries that penetrate the brain and maintain its rich supply of blood.
- Most of the blood supply to the brain runs through the internal carotid arteries. What about knotted or clotted carotids? If the carotid arteries become blocked, the brain receives insufficient blood because the vertebral arteries cannot make up for the deficit. This deficit results in impaired brain function, most often observed as a cognitive (thinking) impairment and dizziness.

Venous Drainage of the Head and Brain

- The external and internal jugular veins are the two major veins that drain blood from the head and neck
- The external jugular veins are more superficial and drain blood from the posterior head and neck region. They empty into the subclavian veins.
- The internal jugular veins drain the anterior head, face, and neck. The deep internal jugular veins drain most of the blood from the venous sinuses of the brain.
- The internal jugular veins on each side of the neck join with the subclavian veins to form the brachiocephalic veins (then to the SVC).
- Do You Know page 352

Blood Supply to the Liver and the Hepatic Portal Circulation

- The delivery of portal blood to the liver is important because the liver plays a critical role in the metabolism of glucose, fats, and protein.
- As the blood flows through the liver, many of the nutrients are extracted from the blood and modified in some way
- The liver has immediate access to large amounts of glucose that is absorbed into the blood following digestion.
- The liver uses the glucose to regulate blood sugar; it can remove excess glucose and store it as glycogen or it can release glucose into the blood to maintain a normal blood sugar.
- The liver prevents nitrogen from entering the general circulation as ammonia. Instead, the nitrogen is excreted by the liver into the blood in the form of urea. Urea is less toxic than ammonia and is easily eliminated by the kidneys.

Hepatic Blood Vessels

- The blood vessels of the liver have a unique arrangement. Three groups of blood vessels are associated with hepatic circulation: the hepatic artery, the hepatic veins, and the hepatic portal system.
  - The hepatic artery is a branch of the celiac trunk (see Fig. 18.5), a large artery that branches off the abdominal aorta. The hepatic artery carries oxygen-rich blood to the liver.
  - The hepatic veins drain blood from the liver and deliver it to the inferior vena cava.
  - The hepatic portal system is a unique arrangement of veins that deliver 80% of the blood flow to the liver. Moreover, this arrangement delivers venous blood to the liver. What is this about? A portal system refers to an arrangement of blood vessels in which the blood from one organ(s) is immediately delivered to a second organ(s) before being returned to the heart and lungs for oxygenation. The hepatic portal system delivers blood, rich in digestive end products, from all the organs of digestion to the liver.
- The portal vein is a large vein that carries blood from the organs of digestion to the liver
- Portal vein formed by the union of two large veins: the superior mesenteric vein and the splenic vein
  - The superior mesenteric vein receives blood from the small intestine (where most digestion and absorption occur) and the first part of the large intestine.
  - The splenic vein receives blood from the stomach, spleen, and pancreas.
- The splenic vein receives blood from the inferior mesenteric vein, which drains the distal part of the large intestine.
- The important point: the portal vein delivers blood rich in digestive end products directly to the liver.
- Both the hepatic artery and portal vein carry blood toward the liver
- The hepatic artery carries oxygen-rich blood, and the portal vein carries blood rich in the products of digestion to the liver but poor in oxygen content
- Once in the liver, blood from both the hepatic artery and portal vein perfuses the capillaries called hepatic sinusoids.
- The sinusoids have large pores that permit the mixing of arterial and venous blood and facilitate the delivery of digestive end-products to the liver cells
- The sinusoids are also lined with phagocytic cells called Kupffer cells; these cells remove bacteria from portal blood before the blood enters the general circulation.

Fetal Circulation

- Look at your “belly button,” or umbilicus. At one time, you had a long umbilical cord, a lifeline that attached you to a structure called the placenta embedded in the wall of your mother’s uterus. ----As a fetus, you were submerged in amniotic fluid and were unable to eat, breathe, and eliminate as you do now. All your nutrients and oxygen had to be supplied by your mother. Your mother also absorbed much of the waste produced by your tiny body and eliminated it through her excretory organs. The exchange of your nutrients, gases, and waste occurred at the placenta.
- Figure 18.9 page 354
- Table 18.2 page 355
  - Umbilical blood vessels. The umbilical cord contains three blood vessels: one large umbilical vein and two smaller umbilical arteries. The umbilical vein carries blood rich in oxygen and nutrients from the placenta, embedded in the mother’s uterine wall, to the fetus. The two umbilical arteries carry carbon dioxide and other waste from the fetus to the placenta.
    - NOTE: In the fetal circulation, the umbilical vein carries oxygen-rich blood, whereas it is the umbilical arteries that carry oxygen-poor blood.
  - Ductus venosus. Blood flows through the umbilical vein from the placenta into the fetus. Within the body of the fetus, the umbilical vein branches. Some blood flows through one branch to the fetal liver. Most of the blood, however, bypasses the liver and flows through the ductus venosus into the IVC. After birth, the ductus venosus closes and serves no further purpose.

Fetal Circulation

- Because the deflated fetal lungs are not used for gas exchange, they have no need for blood to be pumped through the pulmonary circulation.
- Two modifications in the fetal heart and large vessels reroute most of the blood past the lungs. These are the foramen ovale and the ductus arteriosus:
  - Foramen ovale. The foramen ovale is an opening in the interatrial septum of the heart. This opening allows most of the blood to flow from the right atrium directly into the left atrium thereby bypassing the fetal lungs.
  - Ductus arteriosus. Although most blood flows through the foramen ovale into the left atrium, some blood enters the right ventricle and is pumped into the pulmonary trunk. How does this blood bypass the lungs? The fetal heart has a short tube called the ductus arteriosus that connects the pulmonary trunk with the descending aorta. Blood pumped into the pulmonary trunk bypasses the lungs by flowing through the ductus arteriosus directly into the aorta. After birth, these fetal structures close. Failure of fetal structures to close after birth is the basis for a variety of congenital heart defects.

Fetal Circulation

- Why is it not a good idea for a pregnant woman to take aspirin or a similar drug, such as the nonsteroidal antiinflammatory drugs (NSAIDs)? Naturally secreted prostaglandins help keep the ductus arteriosus open. Drugs such as aspirin and indomethacin block prostaglandin synthesis, thereby causing a premature closure of the ductus arteriosus. Not good!
- Figure 18.9 page 354
  - Blood vessels carrying oxygenated blood are in red; these are usually the arteries. Vessels carrying unoxygenated blood are in blue; these are usually veins. Note, however, that the umbilical vein is red, indicating oxygenated blood. The umbilical arteries are blue, indicating unoxygenated blood.
  - Note the color of the upper portion of the vena cava. The adult venae cavae are colored blue because they contain unoxygenated blood. The fetal venae cavae, however, are violet, indicating that the blood is a mixture of unoxygenated blood (coming from the metabolizing fetal tissue) and oxygenated blood (coming from the umbilical vein). Note also the color of the blood in the fetal aorta; it is not the bright red that is characteristic of the adult aorta. The adult aorta carries only oxygenated blood, but the fetal aorta has a mixture of oxygenated and unoxygenated blood.

Pulse

- The ventricles pump blood into the arteries. The blood causes an alternating expansion and recoil of the arteries with each beat of the heart. This alternating expansion and recoil creates a pressure wave (similar to vibration), which travels through all the arteries. This wave is called the pulse.
- Figure 18.10 page 355
- Because it is caused by the rhythmic contraction of the ventricles of the heart, the pulse is often described as a “heartbeat that can be felt at the wrist.”
- By feeling a person’s pulse, you can determine the heart rate
- You can also assess the pulse for its strength
- At times, the heart contracts so weakly that the heartbeat cannot be felt over the radial artery; this happens in a person who has lost a lot of blood and is in shock ---His pulse may be described as being “rapid and thready.” A pulse may also be described as “full or bounding,” as happens in a person with excess blood volume
- The pulse may be absent if the artery is blocked or occluded
- . A pulse deficit is a difference between the heart rate as determined by auscultation at the apex of the heart and the heart rate as determined by palpation of the radial artery
- In certain clinical conditions, such as atrial fibrillation, the heart beats, but it does so ineffectively. Consequently, the vibration set up in the arterial wall is too weak to be felt at the wrist (radial pulse). The underlying cause of a pulse deficit is easily detected with an electrocardiogram (ECG). Thus, a correct assessment of the pulse can provide much useful information about the patient’s condition.
- Sum It Up page 356