

Blood Vessels

Overview

The three major types of blood vessels are

- arteries which branch into smaller and smaller structures and carry blood away from the heart
- veins which merge into larger and larger vessels as they carry blood back to the heart
- capillaries which are the smallest vessels and directly serve the needs of the tissues

Arterioles are vessels smaller than the arteries that carry the blood into the capillary beds. Venules are vessels smaller than veins that carry blood away from the capillary beds.

The larger blood vessels have three distinct layers or tunics that surround the blood-containing space, the lumen. The tunica interna (or tunica intima) consists of simple squamous cell epithelium and associated connective tissue. This epithelium is continuous with the endocardium of the heart. The tunica media is mostly circularly arranged smooth muscle cells and sheets of elastin. The smooth muscle is innervated by sympathetic nerve fibers allowing the vessel to vasoconstrict or vasodilate to maintain blood pressure. The tunica externa (or tunica adventitia) is made up of collagen fibers to protect the vessel. The very largest vessels have tiny blood vessels within the tunica externa called the vasa vasorum.

Arteries

The large arteries near the heart, the aorta and its major branches, have the largest lumens and the most elastin allowing these vessels to expand and withstand large differences in pressure. As these arteries divide the subsequent branches have greater amounts of smooth muscle and less elastin. The larger arterioles have all three tunics but the smaller ones are little more than a layer of smooth muscle around an epithelial lining.

Capillaries

These are the smallest blood vessels and consist of only a tunica interna (epithelium and basement membrane). RBC's pass through capillaries in single file. It is through the capillaries that oxygen, nutrients and hormones are exchanged with the tissues. Some epithelial cells of the capillaries are continuous, held together by tight junctions. Others are leaky, having pores in the epithelium and an incomplete basement membrane allowing large molecules and WBC's to pass through the walls.

Capillaries form interweaving networks called capillary beds consisting of two types of vessels: a metarteriole – thoroughfare channel which connects the arteriole and the venule at opposite ends of the bed, and true capillaries. A cuff of smooth muscle fibers, called a capillary sphincter, surrounds the root of each true capillary and acts as a valve to regulate blood flow. When the sphincters are closed, the blood is shunted through the metarteriole – thoroughfare channel.

Veins

Blood collecting from the capillaries drains into small venules which are very porous allowing fluid and WBC's to pass through easily. They consist mostly of epithelium. Larger venules have a few layers of smooth muscle and a thin tunica externa. Venules join to form veins which like arteries have three distinct tunics but have thinner walls (with less smooth muscle and elastin) and larger lumens than arteries. The tunica externa is the largest of the layers. About 2/3 of the body's blood supply is found in the veins at any one time.

Blood pressure in the veins is low because the effects of ventricular contraction are not present. To prevent backflow, veins have valves formed from folds in the tunica interna. They are most abundant in the extremities where the upward flow of blood is opposed by gravity.

Venous sinuses are specialized, flattened veins with thin walls. They are supported by the surrounding tissue.

Veins that are dilated due to stretched walls and incompetent valves are called varicose veins. This often occurs if there is a restriction hindering the return flow of blood to the heart. Superficial veins (often in the legs) receive little support from underlying tissues.

Anastomoses are formed when veins or arteries unite. Arterial anastomoses provide alternative routes for blood to reach an area. Venous anastomoses are more common.

Blood Pressure

Blood flow is the volume of blood flowing through a vessel in a specific time measured in ml/min. Blood pressure is the force per unit area exerted by the blood on the vessel wall and is measured in mmHg. In order for blood to flow, there must be a difference in pressure. Resistance is the opposition to flow (friction) and is a function of blood viscosity, vessel length and vessel diameter.

$$F = \Delta P/R$$

Systemic blood pressure is highest in the aorta and reaches 0 in the right atrium. Arterial blood pressure is a function of the elasticity of the arteries and the amount of blood being pumped through them at any one time. Systolic pressure occurs because of ventricular contraction and diastolic pressure because of relaxation. The difference between the two is the pulse pressure.

Control of blood pressure is complex involving the interaction of a number of systems. Neural controls alter blood distribution to respond to the demands of various organs and by maintaining adequate pressure by altering blood vessel diameter. The latter is regulated by sympathetic neurons in the medulla oblongata. Baroreceptors are neural receptors located in the aortic arch and carotid sinuses (dilations in the internal carotid arteries). When stretched they initiate a reflex arc to the medulla resulting in vasodilation and a drop in blood pressure. Chemoreceptors detect sharp drops in O₂ and increases in CO₂ resulting in vasoconstriction leading to a rise in blood pressure which speeds the return of blood to the heart and lungs. Higher brain centers (hypothalamus) also may have significant effects on blood pressure.

A number of hormones, such as the adrenal medulla hormones, ADH, NO, and inflammatory chemicals, e.g. histamine, also regulate blood pressure by vasoconstriction or regulating blood volume. Rises in blood pressure also induce the kidneys to remove fluid from circulation into the tubules. When blood pressure declines, the kidneys release renin resulting in an increase in angiotensin II, a potent vasoconstrictor.

Hypertension is high blood pressure and is the major cause of heart failure, vascular disease, renal failure and stroke. The heart must work harder to counteract this condition that eventually results in a weakening of the heart. Primary hypertension refers to hypertension for which no underlying cause has been established (about 90% of the cases). Diet, obesity, age, race, heredity, stress and smoking may all play a part. Secondary hypertension is due to identifiable disorders such as kidney disease or hormonal disorders.

Circulatory Shock

Blood flow through the body tissues is called tissue perfusion. Inadequate perfusion is referred to as circulatory shock. The most common type of shock is hypovolemic shock, a loss of blood volume. Vascular shock refers to a significant drop in blood pressure due to extreme vasodilation. Cardiogenic shock occurs when inadequate pumping of the heart fails to provide enough circulation to the tissues.

The Major Arteries

The ascending aorta leaves the left ventricle and bends sharply to the left forming the aortic arch. The descending aorta runs inferiorly through the thoracic cavity and is called the abdominal aorta after passing through the diaphragm. There are three branches leaving the aortic arch – the brachiocephalic, the left common carotid, and the left subclavian. From the subclavians branch the right and left vertebral arteries which pass through the transverse foramina of the cervical vertebrae and supply part of the brain. The brachiocephalic branches into the right common carotid and the right subclavian arteries. The right and left common carotids both have two branches – the internal carotids which supply the brain and orbits and the external carotids which supply the head and neck.

The right and left axillary arteries which pass through the axillae, are branches of the right and left subclavians. The major branch of the axillary is the brachial artery which itself branches into the radial and ulnar arteries.

The abdominal aorta splits into the right and left common iliac arteries. The major branches of these are external iliacs which pass through the pelvis and become the right and left femoral arteries. The femoral artery becomes the popliteal artery and passes through the intercondylar notch of the femur. The popliteal branches into the anterior and posterior tibial arteries. The posterior tibial passes posteriorly to the medial malleolus. At the level of the ankle the anterior tibial becomes the dorsalis pedis artery in the dorsal foot.

Soon after the aorta passes through the diaphragm, there is a large, ventral, unpaired branch called the celiac trunk. This quickly divides into three branches: the left gastric, the common hepatic, and the splenic arteries. Two other unpaired arteries of the abdominal aorta are the superior and inferior mesenteric arteries supplying the small and large intestines. Between these two are the paired renal arteries and the paired testicular (or ovarian) arteries.

Deoxygenated blood leaves the right ventricle through the pulmonary trunk which divides into the right and left pulmonary arteries. The right divides into three lobar arteries and the left into two lobar arteries.

When the left ventricle contracts, a pressure wave is sent along the elastic arteries through the arterial tree. This is referred to as a pulse and can be felt by compressing an artery near the surface against deeper, firmer tissue. By counting the pulses per minute, a heart rate can be determined. A radial pulse is taken most frequently, but other arteries from which a pulse is frequently taken include the carotid, brachial, temporal, ulnar, femoral, popliteal, posterior tibial, and dorsalis pedis arteries.

The Major Veins

Two veins of the forearm, the radial and the ulnar, join to form the brachial vein. Another vein of the forearm, the basilic, joins the brachial to become the axillary. The cephalic vein also drains the lower and upper arm and joins the axillary to become the subclavian. An anastomosis of the cubital region, the medial cubital vein, joins the cephalic and the basilic. The subclavians are joined first by the external jugulars, then by the internal jugulars and become the brachiocephalic veins. The two brachiocephalics join to become the superior vena cava which enters the right atrium.

The anterior and posterior tibial veins unite and form the popliteal vein which crosses the back of the knee and becomes the femoral vein. Another vein that drains the foot and medially runs the length of the leg is the great saphenous vein. This unites with the femoral and becomes the external iliac vein. The external iliac unites with the internal iliac to become the common iliac vein. The right and left common iliacs unite to form the inferior vena cava.

The superior mesenteric vein drains the entire small intestine. Rich with nutrients the superior mesenteric is joined by the inferior mesenteric and the splenic veins to form the hepatic portal vein. The hepatic portal vein enters the liver and branches again and again, eventually into small capillaries. After filtering through the liver, the vessels then merge into larger vessels until the right and left hepatic veins enter the inferior vena cava. The right and left renal veins drain the kidneys. The right gonadal vein (testicular or ovarian) enters the inferior vena cava directly; the left gonadal vein enters the left renal vein.

