Unit 1 Lecture 4

BLOOD VESSELS AND HEMODYNAMICS

Arteries carry blood from the heart to the tissues. They branch into medium size arteries that in turn branch into arterioles. Arterioles branch into capillaries in which substances are exchanged with the tissues through the walls of the capillaries. The capillaries unite to form venules, which in turn unite to form veins. Veins transport blood back to the heart. *Vasa vasorum* are the blood vessels that carry oxygen and nutrients to the vessels.

Anatomy of Blood Vessels

Arteries have three layers. The tunica interna is the inner wall. The tunica media (middle layer) is composed of elastic fibers and smooth muscle. The tunica externa is the outer wall and is composed of elastic and collagen fibers. A lumen is the hollow center of the vessel for blood flow. The functional properties of arteries are elasticity that allows blood vessels expand to accommodate the blood expelled during ventricular contraction and contractility; vasodilation is an increase in vessel size whereas vasoconstriction is a decrease in vessel size.

Arterioles are very small microscopic arteries that deliver and regulate blood to the capillaries through vasoconstriction (smooth muscle of arteriole contracts) and vasodilation (smooth muscle of arteriole relaxes). They are also composed of same three tissue layers as the arteries.

Capillaries connect the arterioles to the venules and are found near almost every cell in the body. Their function is to permit the exchange of nutrients, gases and wastes between blood and tissue cells. The cell walls have only one layer, an endothelial cell. A metarteriole is a vessel that originates at an arteriole and empties into a venule and functions in bypassing capillary beds when those capillaries are not used; therefore serve as a low resistance path for blood flow. True capillaries emerge from an arteriole or metarteriole but are not on the direct path of arteriole to vein. Precapillary sphincters control the flow of blood into the capillary.

The most important mechanism for exchange of nutrients and wastes in the capillaries is diffusion from a higher concentration to lower. Other methods include vesicular transport (transcytosis) whereby substances become enclosed in tiny vesicles that enter the endothelial cells by endocytosis and leave by exocytosis. Another method is bulk flow (filtration and reabsorption). This is a passive process that involves the movement of large number of ions, molecules or particles in the same direction. Normally filtration from one end of the capillary will equal reabsorption at the other end (Starling's Law of the capillaries). Sometimes edema occurs when the

rate of fluid filtration out of the capillary bed exceeds the ability of the lymphatic drainage system to return filtered fluid to the vascular system.

Veins and Venules

Capillaries combine to form small veins called venules. Venules unite to form veins. They are composed of the same three layers as arteries except that the tunica interna and tunica media are thinner and the tunica externa is thicker than those found in arteries. Veins in the limbs contain valves that prevent the backflow of blood. Veins and venules serve as the main blood reservoirs because they hold @ 60% of the blood in the body. Venous return to the heart is aided by the skeletal muscle and respiratory pumps.

Hemodynamics: Physiology of Circulation

The volume of blood that flows through any tissue in any given time period is called blood flow. The velocity decreases as it flows from the arteries to arterioles to capillaries (increasing resistance) and increases as it leaves capillaries on return trip to the heart through venous system (decreasing resistance). The time it takes for the blood to complete the entire circuit is @ 1 minute. The volume of blood flow or cardiac output is roughly equal to 5.25 l/min. Factors that influence output includes blood pressure, which is the pressure exerted on a blood vessel wall by blood and resistance, which is the opposition to blood flow as a result of friction between blood and blood vessels. Blood pressure (BP) equals cardiac output times the peripheral resistance. In the aorta BP is usually 120/80 (systolic/diastolic). Resistance to blood flow is highest in the arterioles causing BP to decrease from 85 mm Hg to 35 mm Hg. By the time blood reaches the right atrium, BP = 0 mm Hg.

Factors that influence resistance are blood viscosity, total blood vessel length, and blood vessel radius. The major function of the arterioles is to control systemic vascular resistance by dilation or constriction.

Blood flows down a pressure gradient from the highest pressure in the arteries to the lowest pressure in the veins. The pressure created when the ventricles contract is called driving pressure and is necessary to keep the fluid (blood) moving in the system. If there were no pressure gradient, there would be no blood flow. Movement creates friction which causes resistance. Resistance of a fluid flowing through a tube increases as length of the tube and viscosity thickness) of the fluid increases. Resistance also increases as the radius of the tube (blood vessels) decreases. Radius has the most impact on resistance. If resistance increases, flow decreases. If resistance decreases, flow increases. Flow rate is the volume of blood that passes a point in the system per unit of time. It is measures as liters per minute. Flow rate is determined by the pressure gradient and by the resistance of the system. Velocity of flow is how far a volume of blood will travel in a given period of time. It is expressed as centimeters per minute. The primary determinate of velocity of flow is the total cross-sectional area of the vessel.

Venous return refers to the amount of blood flowing back to the heart. At steady state, venous return and cardiac output must be equal. Blood flows toward the atria because pressure at the atria is 0 mm Hg. Other mechanisms that help venous return include the skeletal muscle pump whereby contraction of leg muscles drives blood toward heart and the respiratory pump in which the movement of the diaphragm causes pressure changes in the thoracic cavity which drives blood toward heart.

Control of blood pressure and blood flow is done through negative feedback systems that control BP by adjusting heart rate, stroke volume, systemic vascular resistance, and blood volume. Blood flow to the brain remains constant. The Cardiovascular Center, found in the medulla of the brain, receives inputs from higher brain regions, baroreceptors (pressure sensitive sensory neurons), and chemoreceptors (monitor CO_2, O_2 and pH). It sends outputs to both sympathetic and parasympathetic fibers of the autonomic nervous system. Sympathetic stimulation increases heart rate and contractility. Parasympathetic impulses decrease heart rate.

Hormonal regulation of blood pressure can either increase or decrease the pressure. When blood volume decreases, the Renin-angiotensin-aldosterone system is stimulated. The release of epinephrine and norepinephrine and antidiuretic hormone (ADH) also increases blood pressure whereas atrial natriuretic peptide (ANP) and epinephrine cause blood pressure to decrease. You will note that epinephrine can cause either an increase or decrease depending on the receptors it acts on.

Autoregulation refers to local automatic adjustment of blood flow to any given region is driven mainly by the tissue's need for oxygen.
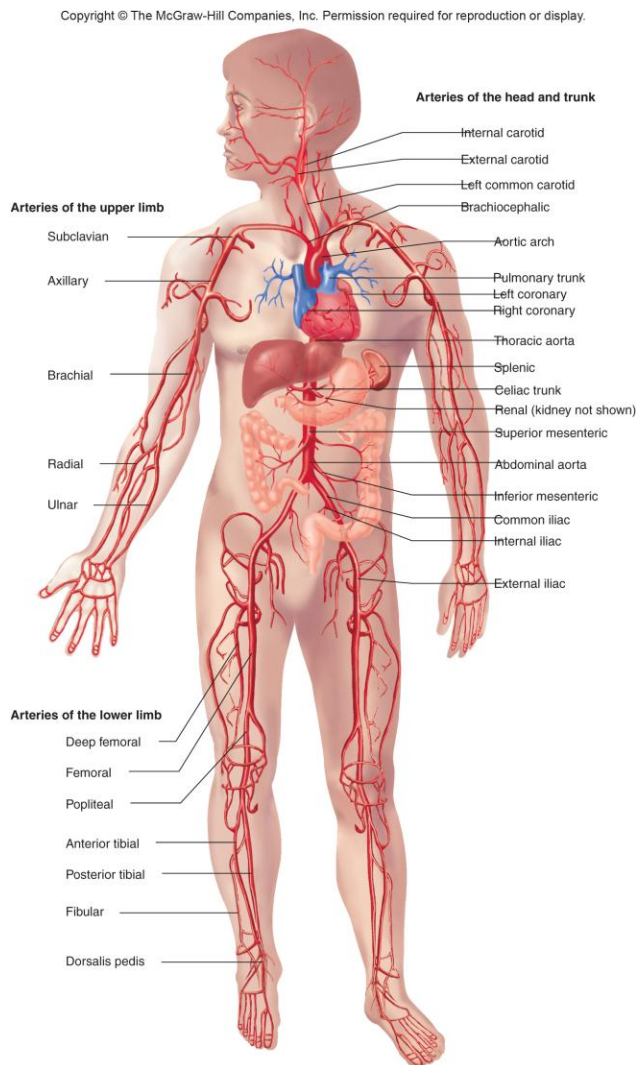
Shock and Homeostasis

Shock is an inadequate cardiac output that results in a failure of the CVS to deliver enough nutrients and O2 to body cells. There are four types of shock: hypovolemic (sudden blood loss), cardiogenic (the heart fails to pump adequately often due to a heart attack), vascular (due to a decrease in vascular resistance), and obstructive (blood flow is blocked to a site such as a pulmonary aneurysm). Signs include cool, clammy pale skin due to vasoconstriction, tachycardia, weak but rapid pulse, sweating, hypotension, and altered mental status due to cerebral ischemia.

The stages of hypovolemic shock due to blood or plasma loss. In Stage I (compensated), symptoms are minimal and can be reversed even with as much as a 10% blood loss. Stage II (decompensated and progressive) occurs when blood volume drops >15-25%. Compensatory mechanisms cannot maintain adequate perfusion and the person needs medical help else positive feedback systems will contribute to decreasing cardiac output. Stage III is irreversible. Stage III Shock leads to certain death.

Circulatory Routes

In the **pulmonary circuit**, the lungs receive blood from the heart via the pulmonary arteries and send it back to the heart via pulmonary veins. The main difference between pulmonary circulation and systemic circulation is that pulmonary arteries carry deoxygenated blood and pulmonary veins carry oxygenated blood whereas systemic arteries carry oxygenated blood and systemic veins carry deoxygenated blood. The **systemic circulation** carries blood from the left ventricle throughout the body and returns blood to the right atrium.

Arteries of the head and trunk
Internal carotid
External carotid
Left common carotid
Brachiocephalic
Aortic arch
Pulmonary trunk
Left coronary
Right coronary
Thoracic aorta
Splenic
Celiac trunk
Renal (kidney not shown)
Superior mesenteric
Abdominal aorta
Inferior mesenteric
Common iliac
Internal iliac
External iliac

Arteries of the upper limb
Subclavian
Axillary
Brachial
Radial
Ulnar

Arteries of the lower limb
Deep femoral
Femoral
Popliteal
Anterior tibial
Posterior tibial
Fibular
Dorsalis pedis

Arteries

Blood vessels are continuous with branches coming off of arteries and arterioles. The names of the vessels change based on their location in the body. Arteries get smaller as they carry blood away from the heart. The first portion of the aorta is the ascending aorta. From it branches the L/R coronary arteries that supply blood to the heart. The ascending aorta becomes the aortic arch. The [brachiocephalic trunk](#) branches into the right common carotid (gives rise to the internal and external carotid artery), the right subclavian artery, and the left common carotid artery (gives rise to the internal and external carotid artery). All come off the aortic arch. Inside of the brain the L/R internal carotids along with the basilar artery form the [circle of Willis](#). Associated with the circle of Willis are the posterior and anterior communicating arteries. The function of the circle of Willis is to equalize BP to the brain and produce alternate routes of blood flow to the brain. As the aorta descends it becomes the [thoracic aorta above the diaphragm and then the abdominal aorta](#) below the diaphragm. The thoracic aorta supplies the pericardial, esophageal, bronchial and mediastinal viscerally and the intercostal, costal, superior phrenic branches parietally.
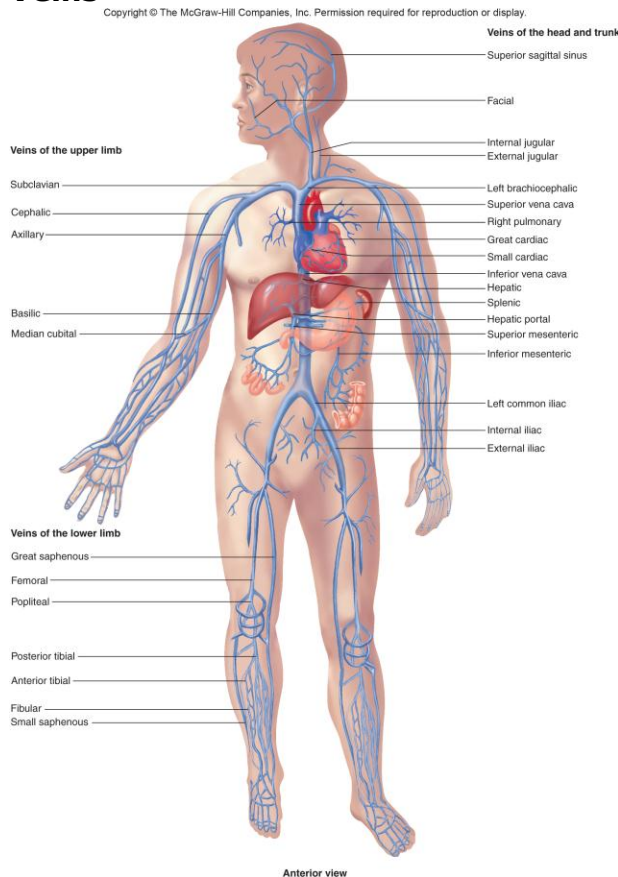
Branches off the abdominal aorta include the celiac (gives rise to the gastric, splenic, and common hepatic arteries), phrenic, superior (serves the small intestine and part of the large intestine) and inferior mesenteric (serves the remaining portion of the large intestine), suprarenal, renal, and gonadal arteries.

In the arm, the subclavian artery becomes the brachial artery then divides into the radial and ulnar arteries, reunites to the palmar.

Arteries of the Pelvis and Lower Extremities

The abdominal aorta divides to become the common iliac which divides to become the internal iliac and external iliac which becomes the femoral and then the popliteal. The popliteal divides into the anterior and posterior tibial.

Veins

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Veins of the head and trunk
- Superior sagittal sinus
- Facial
- Internal jugular
- External jugular
- Left brachiocephalic
- Superior vena cava
- Right pulmonary
- Great cardiac
- Small cardiac
- Inferior vena cava
- Hepatic
- Splenic
- Hepatic portal
- Superior mesenteric
- Inferior mesenteric
- Left common iliac
- Internal iliac
- External iliac

Veins of the upper limb
- Subclavian
- Cephalic
- Axillary
- Basilic
- Median cubital

Veins of the lower limb
- Great saphenous
- Femoral
- Popliteal
- Posterior tibial
- Anterior tibial
- Fibular
- Small saphenous

Anterior view

Veins bring blood to the heart. Venules merge to become larger veins. Most (60%) of the blood in the body is stored in the venous system. The main veins that empty into the heart are the coronary sinus that drains heart blood, the superior vena cava which drains blood from upper regions and the inferior vena cava that drains blood from lower regions.

Veins of the Head and Neck

The exterior jugular drains blood from superficial structures of the skull and from deep face veins and empties it into the subclavian veins. The vertebral vein also drains into the subclavian vein. The internal jugular drains blood from the brain. The subclavian joins the internal jugular to form the brachiocephalic. The R/L brachiocephalics unite to form the superior vena cava which empties into the right atrium of the heart.

Veins of the upper Extremities

The dorsal venous arch (DVA) drains into the basilic which drains into the axillary and into the cephalic which merges with the accessory cephalic to

form the upper cephalic vein and that drains into the axillary. The palmer venous arch drains into the median antebrachial which drains into the median cubital (used in phlebotomy, IV) which unites with the basilic and drains into the axillary at about the first rib. In the deep veins of the upper extremities, the dorsal metacarpal drains into the radial which drains into the brachial as does the ulnar which drains into the brachial. As mentioned before, the brachial drains into the axillary which drains into the subclavian.

Veins of the Thorax

The zygous system drains blood from the thoracic veins and can serve as an alternate pathway to the inferior vena cava. The azygous begins as a continuation of the right ascending lumbar vein and receives blood from the left intercostal, esophageal, mediastinal, pericardial and bronchial veins and empties into the superior vena cava. The hemiazygous receives blood from some of the intercostal veins, some esophageal and mediastinal veins and empties into the azygous. The accessory hemiazygous receives blood from the upper left intercostal veins and the left bronchial and empties into the azygous.

Veins of the Abdomen and Pelvis

The lumbar, hepatic, suprarenal, right gonadal and renal veins all drain into the inferior vena cava. The left gonadal drains into the left renal.

Veins of the Lower Extremities

The deeper veins of the legs (anterior and posterior tibial) unite to form the popliteal. The small saphenous vein empties into the popliteal vein which then joins the femoral vein. The great saphenous (longest vein in the body) also joins the femoral vein. The femoral becomes the external iliac. The internal iliac unites with the external iliac to form the common iliac. The R/L common iliac veins unite to form the inferior vena cava.

Hepatic Portal Circulation

In addition to receiving arterial blood via the hepatic artery, much venous blood is drained through the liver. Blood from the gastrointestinal tract and the spleen is sent to the liver where the liver stores nutrients from digested and absorbed food, detoxifies harmful substances, and destroys bacteria by phagocytosis. Blood from the right gastric, pyloric, right gastroepiploic, vessels from the small intestine and the right side of the large intestine all drain into the superior mesenteric vein. Vessels from the left side of the large intestine drain into the inferior mesenteric which joins the splenic vein. Also adding tributaries to the splenic are vessels from the left of the stomach. The splenic and the superior mesenteric unite to form the hepatic portal vein. The cystic vein (from the gallbladder) also flows into the hepatic portal vein. All blood drains from the liver via the hepatic vein into the inferior vena cava.