The Cardiovascular System

BIO 250 Human Anatomy & Physiology

Preview of Heart Action

http://www.youtube.com/watch?v=D3ZDJgFDdk0&NR=1

The CV system provides oxygen & nutrients to tissues-removes wastes.

- It consists of a muscular pumping heart
- Blood vessels filled with blood
  - Arteries carrying blood away from the heart
  - Veins carrying blood back to the heart
  - Capillaries where exchanges of materials occur between the blood and tissue fluids
Structure of the Heart

Size and location of the heart
- The heart is about 14 centimeters long and 9 centimeters wide. (5.5 inches x 3.5 inches)
- It is located within the mediastinum and rests on the diaphragm.

Coverings of the heart
- A layered pericardium encloses the heart.
- The pericardial cavity is a space between the visceral and parietal layers of the pericardium.
Wall of the heart

- The wall of the heart has three layers.
- These layers include:
  - epicardium (also visceral pericardium)
  - myocardium
  - endocardium

Heart chambers

- The heart is divided into four chambers:
  - Two Atria
  - Two Ventricles
  - The atrium and ventricle on each side of the heart communicate through an atrioventricular orifice.

Right chambers and valves

- The right atrium receives blood from the venae cavae and coronary sinus.
- The tricuspid valve guards the right atrioventricular orifice.
- The right ventricle pumps blood into the pulmonary trunk.
- A pulmonary semilunar valve guards the base of the pulmonary trunk.
Left chambers and valves

- The left atrium receives blood from the pulmonary veins.
- The bicuspid (mitral) valve guards the left atrioventricular orifice.
- The left ventricle pumps blood into the aorta.
- An aortic semilunar valve guards the base of the aorta.
- Narrowing of a valve opening called **stenosis**
The skeleton of the heart consists of fibrous rings that enclose the bases of the pulmonary artery, aorta, and atrioventricular orifices. The fibrous rings provide attachments for valves and muscle fibers, and prevent the orifices from distorting excessively during ventricular contractions. Skeleton of the heart also provides a physical separation of the muscle cells of the atria from those of the ventricles.
Path of blood through the heart

- Blood that is relatively low in oxygen concentration and high in carbon dioxide concentration enters the right side of the heart from the venae cavae and is pumped into the pulmonary circulation.
- After the blood is oxygenated in the lungs and some of its carbon dioxide is removed, it returns to the left side of the heart through the pulmonary veins.
- From the left ventricle, it moves into the aorta.

Blood supply to the heart

- The coronary arteries supply blood to the myocardium.
- It is returned to the right atrium through the cardiac veins and coronary sinus.
- Interruption of blood flow to the myocardium can result in infarctions.
Heart sounds

- Heart sounds can be described as lub-dup.
- Heart sounds are due to the vibrations the blood and valve movements produce during the cardiac cycle.
- The first heart sound (lub) occurs as A-V valves close, and the second heart sound (dup) is associated with the closing of the pulmonary and aortic valves.
Heart Actions

- Cardiac cycle
  - The atria contract while the ventricles relax; the ventricles contract while the atria relax.
  - Contraction called systole
  - Relaxation called diastole
  - Relaxation of atria and ventricles together called double diastole
- Pressure within the chambers rises and falls in repeated cycles.
- Ventricles about 70% full before atria contract.

Operation of Atrioventricular Valves

Operation of Semilunar Valves
Cardiac muscle fibers

- Cardiac muscle fibers interconnect to form a **functional syncytium**.
- If any part of the syncytium is stimulated, the whole structure contracts as a unit.
- Cardiac muscle cells have a long absolute refractory period that makes the heart incapable of tetany.

- Most of the Ca++ ions necessary for actin-myosin interaction come from outside the cell, via calcium channels, rather than from the sarcoplasmic reticulum.
- Except for a small region in the floor of the right atrium, the fibrous skeleton separates the atrial syncytium from the ventricular syncytium.
Structure of Cardiac Muscle Cell

Cardiac conduction system

- This system, composed of specialized cardiac muscle tissue, initiates and conducts depolarization waves through the myocardium.
- Impulses from the S-A node pass slowly to the A-V node; impulses travel rapidly along the A-V bundle and Purkinje fibers.
- Muscle fibers in the ventricular walls are arranged in whorls that squeeze blood out of the contracting ventricles.
Regulation of the cardiac cycle

- Physical exercise, body temperature, and concentration of various ions affect heartbeat.
- Branches of sympathetic and parasympathetic nerve fibers innervate the S-A and A-V nodes.
  - Parasympathetic impulses decrease heart action; sympathetic impulses increase heart action (affect heart rate and strength of contraction).
- The cardiac center in the medulla oblongata regulates autonomic impulses.

[Image of the heart with labeled parts]

[Image of the heart with labeled parts and a video link]

[Link: http://www.youtube.com/watch?v=iX6HnUyzgQ0&NR=1]
The electrocardiogram

- P-wave occurs as the atria depolarize
- QRS-complex occurs as the ventricles depolarize
- T-wave occurs as the ventricles repolarize
- P-R Interval extends from beginning of P-wave to the beginning of the QRS-complex
- Q-T Interval extends from the end of the P-R Interval to the end of the T-wave
Cardiac Output

- **Cardiac Output** is the amount of blood discharged from each ventricle per minute
- **Stroke Volume** is the amount of blood discharged from the ventricle with each beat
- **Heart Rate** is the number of beats per minute
- **Cardiac Output** = Stroke Vol $\times$ Heart Rate
- e.g. 70 ml per beat $\times$ 75 beats per minute gives a cardiac output of 5,250 ml per minute (5.25 l.)
- Can be increased to 20-25 l. or 35 l. in athletes

Heart Rate

- Measured from pulse
- Infants have HR of 120 beats per minute or more
- Young adult females avg. 72 - 80 bpm
- Young adult males avg. 64 to 72 bpm
- HR rises again in the elderly
- Tachycardia: persistent, resting adult HR > 100
  - stress, anxiety, drugs, heart disease or ↑ body temp.
- Bradycardia: persistent, resting adult HR < 60
  - common in sleep and endurance trained athletes (↑ SV)
Blood Vessels

- The blood vessels form a closed circuit of tubes that transport blood between the heart and body cells. The tubes include:
  - arteries
  - arterioles
  - capillaries
  - venules
  - veins.
Arteries and arterioles

- The arteries are adapted to carry relatively high pressure blood away from the heart.
- The arterioles are small muscular branches of arteries.
- The walls of arteries and arterioles consists of layers called tunica interna, tunica media and tunica externa.
- Autonomic fibers that can stimulate vasoconstriction or vasodilation innervate smooth muscles in vessel walls.
Capillaries

- Capillaries connect arterioles and venules. The capillary wall is a single layer of cells that forms a semipermeable membrane.
- Capillary permeability
  - Most capillaries in the body are continuous capillaries
  - Endothelial cells of brain capillaries are tightly fused, forming a blood-brain barrier, through which substances move by facilitated diffusion.
  - Fenestrated capillaries have openings in the capillary walls that are thin slits between adjacent endothelial cells.
  - The sizes of the openings vary from tissue to tissue.
Capillary arrangement and blood flow

- Capillary density varies directly with tissue metabolic rates.
- Regulation of capillary blood flow by precapillary sphincters
- Precapillary sphincters open when cells are low in oxygen and nutrients, and close when cellular needs are met.
Exchanges in capillaries

- Gases, nutrients, and metabolic by-products are exchanged between the capillary blood and the tissue fluid.
- Diffusion provides the means of transport for gases.
- Diffusion dependent on concentration gradients.
- Plasma proteins generally remain in the blood.
- Filtration, which is due to the hydrostatic pressure of blood, causes a net outward movement of fluid at the arterial end of a capillary.
- Osmosis causes a net inward movement of fluid at the venule end of a capillary.
- Some factors cause fluids to accumulate excessively in the tissues (edema).
**Venules and veins**

- Venules continue from capillaries and merge to form veins.
- Veins carry blood to the heart.
- Venous walls are similar to arterial walls, but are thinner and contain less muscle and elastic tissue.
Blood pressure is the force blood exerts against the insides of blood vessels.

Arterial blood pressure

The arterial blood pressure is produced primarily by heart action; it rises and falls with phases of the cardiac cycle.

Systolic pressure occurs when the ventricle contracts; diastolic pressure occurs when the ventricle relaxes and is due to elastic recoil of the larger arteries.
Factors that influence arterial blood pressure

- Blood Pressure (BP) = Cardiac Output (CO) x Peripheral Resistance (PR)
- Heart action, blood volume, resistance to flow, and blood viscosity influence arterial blood pressure.
- Arterial pressure increases as cardiac output, blood volume, peripheral resistance, or blood viscosity increases.

Pressoreceptors or baroreceptors present in the aortic arch and carotid sinus area detect changes in arterial blood pressure.
Control of blood pressure

- Blood pressure (BP) is controlled in part by the mechanisms that regulate cardiac output (CO).
- Cardiac output (CO) depends on the volume of blood discharged from the ventricle (SV) with each beat and on the rate of heartbeat (HR).
  - The more blood that enters the ventricle, the stronger the ventricular contraction, the greater the stroke volume, and the greater the cardiac output (Starlings Law of the Heart).
  - This is the importance of atrial systole.
  - The cardiac center of the medulla oblongata of the brain regulates heart rate.

Control of blood pressure

- Blood pressure (BP) is controlled in part by the mechanisms that regulate peripheral resistance (PR).
- Changes in the diameter of arterioles controlled by the vasomotor center of the medulla oblongata of the brain, regulates peripheral resistance.

Peripheral Blood Pressures

- Blood pressures are usually reported as a fraction: systolic pressure/diastolic pressure (in mm Hg)
- Systemic pressures in larger arteries: 120/80
- Pulmonary pressures in larger arteries: 22/8
- Pulse Pressure = systolic press - diastolic press
- Mean Arterial Pressure = diastolic press + 1/3 of pulse pressure
Speed of Blood Flow in Vessels

Control of Arterial BP

Normal blood pressure in aorta
Vagal tonus maintained constant
Vasomotor tonus maintained constant
Control of Arterial BP

Falling blood pressure in aorta
Vagal tonus diminished which increases cardiac output
Vasomotor tonus increased which increases peripheral resistance
Blood pressure should rise to normal

Control of Arterial BP

Rising blood pressure in aorta
Vagal tonus increased which decreases cardiac output
Vasomotor tonus decreased which decreases peripheral resistance
Blood pressure should fall to normal
Venous blood flow

- Venous blood flow is NOT a direct result of heart action; it depends on skeletal muscle contraction, breathing movements, and venoconstriction.
- Many veins contain flaplike valves that prevent blood from backing up.
- Venous constriction can increase venous pressure and blood flow.

Skeletal Muscles and Venous Return

- Skeletal muscle action, working with one-way valves causes pumping action aiding venous return
Breathing Movements and Venoconstriction on Venous Return

- The action of inhalation causes the diaphragm to descend into the abdominal cavity, compressing the inferior vena cava and forcing blood up into the thoracic cavity and into the heart.
- Circular smooth muscle in the walls of veins can compress the veins and lift blood toward the heart.
- The one-way valves in the veins are important in preventing blood from pooling in the lower extremities.

Paths of Circulation

- The Pulmonary Circuit consists of vessels that carry blood from the right ventricle to the lungs, pulmonary capillaries, and vessels that lead back to the left atrium.
- Pulmonary capillaries exert less pressure (22/8) than those of the systemic circuit (120/80).
- Tightly joined epithelial cells of alveolar walls prevent most substances from entering the alveoli.
- Osmotic pressure rapidly draws water from alveoli into the interstitial fluid and alveoli remain dry.
Paths of Circulation

- The Systemic Circuit is composed of vessels that lead from the left side of the heart to the body cells and back to the right side of the heart.
- It includes the aorta and its branches, systemic capillaries as well as the system of veins that return blood to the right atrium.

Arterial System

Principal branches of the aorta

- The branches of the ascending aorta include the right and left coronary arteries.
- The branches of the aortic arch include the brachiocephalic, left common carotid, and left subclavian arteries.
- The branches of the descending aorta include the thoracic and abdominal groups.
- The abdominal aorta terminates by dividing into right and left common iliac arteries.
Arteries to the neck, head, and brain

These include branches of the subclavian and common carotid arteries.
Arteries to the shoulder and upper limb

- The subclavian artery passes into the arm, and in various regions is called the axillary and brachial artery.
- Branches of the brachial artery include the ulnar and radial arteries.
Arteries to the thoracic and abdominal walls

- Branches of the subclavian artery and thoracic aorta supply the thoracic wall.
- Branches of the abdominal aorta and other arteries supply the abdominal wall.

Arteries to the Abdominal Region

- Three unpaired arteries supply abdominal and pelvic organs
  - Celiac trunk
  - Superior mesenteric artery
  - Inferior mesenteric artery
- Two paired sets of arteries supply abdominal and pelvic organs
  - Renal arteries
  - Gonadal arteries (Ovarian & Testicular)
Arteries to the pelvis and lower limb

- The common iliac artery supplies the pelvic organs, gluteal region, and lower limb.
Venous System

- Characteristics of venous pathways
  - The veins return blood to the heart.
  - Larger veins usually parallel the paths of major arteries.

Veins from the head, neck, and brain

- The jugular veins drain these regions.
- Jugular veins unite with subclavian veins to form the brachiocephalic veins.
Veins from the shoulder and upper limb

- Sets of superficial and deep veins drain the upper limb.
- The major superficial veins are the basilic and cephalic veins.
- The median cubital vein in the bend of the elbow is often used as a site for venipuncture.
Veins from the abdominal and thoracic walls

- Tributaries of the brachiocephalic and azygos vein drain these walls.

Veins from the abdominal viscera

- The blood from the abdominal viscera generally enters the hepatic portal system and is carried to the liver.
- The blood in the portal system is rich in nutrients.
- The liver helps regulate the blood concentrations of glucose, amino acids, and lipids.
- Phagocytic cells in the liver remove bacteria from the portal blood.
- From the liver, hepatic veins carry blood to the inferior vena cava.
Veins from the lower limb and pelvis

- Sets of deep and superficial veins drain these regions.
- The deep veins include the tibial veins, and the superficial veins include the saphenous veins.
Fetal Circulation

There are several modifications to the fetal circulation:

- Foramen ovale (25% entering RA goes to LA)
- Ductus arteriosus (90% from RV through DA)
- About 7.5% of blood returning to right atrium pumped through pulmonary circuit
- Ductus venosus
- Umbilical arteries
- Umbilical vein
- Placental exchange of gases, nutrients and wastes
- Fetal hemoglobin
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