THE CARDIOVASCULAR SYSTEM

Objectives

1. Specify the basic cellular and extracellular components that form the tunics of blood vessels.

2. Identify the following blood vessel types: elastic artery, muscular artery, arteriole, capillary, venule, and inferior vena cava. Be able to describe the basic differences (i.e. diameter, tunics) of an elastic artery, muscular artery, arteriole, capillary, venule, and inferior vena cava.

3. Delineate the various types of capillaries and name an organ where each type can be found.

4. Characterize the three layers of tissue that form the wall of the heart and how each differs in each chamber.

5. Describe the cardiac skeleton and valves, how they are formed, and how they are affected by certain disease states.

I. Structural Plan and Components of the Cardiovascular System

A. Definitions

1. Circulatory system
   a. mechanism for the transport of nutrients, hormones, oxygen, and wastes to different parts of the body
   b. includes the plasma, lymph, and interstitial fluid

2. Blood circulatory system - includes the heart and blood vessels
   a. heart - a modified blood vessel specialized for pumping (intermediate contraction)
   b. pulmonary circulation - circuit of blood between heart and lungs
   c. systemic circulation - distribution of blood from heart (via the aorta) to rest of body and back again (via the inferior & superior vena cava)
   d. volume of system larger than blood volume, so that blood is shunted to different areas as regional requirements vary
B. Basic organization - entire cardiovascular system follows common plan with the composition of a vessel's wall adapted for local demands

2. Tunica Intima - depending on the type of vessel, can include the following: endothelium, basement membrane, loose CT, smooth muscle, internal elastic lamina

2. Tunica Media - depending on the type of vessel, can include the following: smooth muscle, elastic lamellae, loose CT, external elastic lamina

2. Tunica Adventitia - depending on the type of vessel, can include the following: smooth muscle, loose or dense irregular CT, vasa vasorum, peripheral nerves
II. **Blood Vessels**

A. Tissue components of the vascular wall - differentiations under influence of two functional factors

1. Mechanical Factors - primarily blood pressure acting on large vessels determine amount and arrangement of elastic and muscular tissue

2. Metabolic Factors - due to local needs of tissue, involves the microvasculature

B. Endothelium

1. Structure & junctions
   a. simple squamous epithelium lining blood vessels & heart – specialized to mediate and monitor exchange of molecules
   b. rests on a basement membrane – thickness and continuity varies
   c. cells linked by varying numbers and types of cell junctions – strongest in arterioles and loosest in venules
   d. permeability barrier = endothelium + basement membrane
   e. long-lived cells, though replaced by pre-existing cells by mitosis

2. Surface charge - carries a negative charge
   a. repels circulating blood cells and platelets which also carry negative charge
   b. basement membrane carries positive charge - encourages platelet adherence and clotting

C. Vascular smooth muscle - occurs in all vessels except capillaries and some venules

1. Can occur in all three tunics - amount depends on the function of the vessel

2. Orientation
   a. present in tunica intima and tunica adventitia, longitudinally oriented
   b. only cellular component in tunica media of elastic arteries, and dominant cell type in the tunica media of other kinds of vessels

3. Cells held together by gap junctions - spreads innervation
D. Vascular connective tissue cells and ground substance

1. All connective tissue cell types may be present
   a. cells can function as they normally do in the connective tissues, e.g. make fibers, phagocytosis, immunologic reactions, etc.
   b. some also produce vasoactive mediators - affect endothelium and/or smooth muscle

2. Fibers - collagen, elastic, and reticular fibers to various degrees
   a. concentric lamellae - interlacing, fenestrated sheets of elastic fibers, unique to elastic arteries
   b. internal & external elastic laminae - continuous sheets of elastic fibers
   c. collagen imparts tensile strength
   d. elastic fibers insure resilient rebound
   e. smooth muscle cells in tunica media of elastic arteries produce collagen and elastic fibers also present in the tunica media

3. Ground substance fills extracellular space, contributes to physical properties, and diffusion

E. Nutrition of the vascular wall

1. Vasa vasorum - are small blood vessels in the walls of blood vessels >1 mm diameter
   a. visible in the tunica adventitia and outer tunica media
   b. tunica intima and inner tunica media supplied by diffusion from lumen of the large vessel

2. Lymphatics - visible in the tunica adventitia, follow vasa vasorum

3. Nerves - supply all vessels except capillaries
   a. vasomotor sympathetics supply smooth muscle of arterioles
   b. afferents - baroreceptors and chemoreceptors located in tunica adventitia
III. Arteries

A. Elastic (conducting) arteries - aorta and major branches (between heart and muscular arteries)

1. General information - have a high content of elastic fibers, large lumen with a relatively thin wall (about 1/10 the lumen diameter)

2. Tunica intima - about 1/6 of total thickness of wall, tight junctions between endothelial cells, internal elastic lamina indistinct, loose CT

3. Tunica media - thickest layer of wall
   a. smooth muscle between elastic lamellae
   b. 40-70 concentric elastic lamellae in each cross-section
   c. outer elastic lamina indistinct

4. Tunica adventitia
   a. relatively thin and unorganized
   b. vasa vasorum, lymphatics, nerves are present
   c. dense irregular CT

5. Arteriosclerosis - can affect any vessel
   a. first attacks tunica intima - thickens it and incites thrombosis
   b. the tunica media next is eroded - without this layer the vessel is prone to aneurysm and rupture
   c. most aneurysms occur in elastic arteries owing to the thin wall and high blood pressure of these vessels
B. Muscular (distributing) arteries

1. General information - coronary arteries and all of the other named arteries (exclusive of elastic arteries)

2. Tunica intima
   a. gap and occluding junctions between endothelial cells, loose CT
   b. prominent internal elastic lamina

3. Tunica media
   a. smooth muscle cells are the dominant cell type and held together by gap junctions
   b. smooth muscle cells regulate blood flow to organs

4. Tunica Adventitia - same as in elastic arteries

5. These vessels are the ones most often obstructed by disease leading to ischemia and/or infarction

C. Arterioles and Metarterioles

1. General information - <0.1 mm diameter
   a. thickness of wall approximates diameter of lumen
   b. regulation of blood pressure - account for about 1/2 the resistance and maintain relatively high hydrostatic pressure
   c. delivers blood to capillary beds under low pressure
2. Tunica intima
   a. endothelial cells linked by tight junctions and relatively impermeable
   b. little or no subendothelial CT and internal elastic lamina very thin

3. Tunica media
   a. 1-3 layers of smooth muscle that are responsive to sympathetic nerves and metabolic stimuli
   b. metarterioles (also known as pre-capillary sphincters) lead into capillary beds
      - here is where blood pressure is maintained
      - opening and closing of lumen controls blood flow to capillary beds

4. Associated pathologies
   a. arterial hypertension caused by excessive contractile tone in the smooth muscle
   b. hemorrhagic shock - normally loss of 500 ml blood will trigger a reactive contraction of arteriolar smooth muscle in order to maintain normal blood pressure, but a loss of blood volume in excess of 500 ml will make maintenance of normal pressure difficult or impossible without immediate replenishment of the fluid (e.g. blood, plasma, saline)
   c. anaphylactic shock - decreased blood pressure due to arteriolar muscle paralysis
D. Capillaries

1. General information - only endothelium, basement membrane, & an occasional pericyte
   a. sites of blood-tissue exchanges
   b. inner diameter 5-10 μm (1-2 endothelial cells in a cross-section)

2. Continuous capillaries - continuous endothelium & basement membrane
   a. most common type of capillary
   b. occluding junctions between endothelial cells

3. Fenestrated capillaries - attenuated endothelium with continuous basement membrane
   a. large fenestrae within endothelial cells, covered with diaphragms
   b. found in tissues where rapid interchange of gases and metabolites

4. Discontinuous capillaries (sinusoids) - discontinuous basement membrane
   a. larger diameter (30-40 μm) than other types of capillary
   b. large gaps between adjacent endothelial cells
   c. flow of blood slower than in other types of capillary
IV. Veins

A. Venules

1. General information
   a. endothelial cells joined loosely by cell junctions and have a continuous basement membrane
   b. vessels continuous with a capillary network or an arteriole

2. Pericytic venule - also called post-capillary venule
   a. 10-50 μm lumen diameter, tunica intima only
   b. loose organization of cell junctions and gaps between endothelial cells
   c. usually possesses one or more pericytes
   d. the usual vessel involved in cellular movement into and out of the tissue space

3. Muscular venule - usually associated with arterioles
   a. endothelial cells joined by extensive tight and gap junctions
   b. tunica media contains 1-3 smooth muscle cells
   c. tunica adventitia relatively thick

B. Small Veins - 0.2-1.0 mm diameter

1. Endothelial cells joined by extensive tight and gap junctions

2. Tunica media contains 2-4 layers of smooth muscle cells

3. Tunica adventitia the thickest layer
C. Medium Veins - 1-10 mm diameter

1. Endothelial cells joined by extensive tight and gap junctions

2. Tunica intima may form semilunar valves - especially numerous in limbs, prevent gravitational backflow of blood

3. Tunica media contains 4-10 layers of smooth muscle cells

4. Tunica adventitia the thickest layer

D. Large Veins

1. General information
   a. taken together veins form an important blood reservoir, normally have 4-5 times the volume of blood in corresponding arteries
   b. includes major named veins and their main tributaries
   c. these vessels are larger than 10 mm
   d. walls are thin, approximately 1/20 the lumen's diameter

2. Tunica intima
   a. endothelium held tightly together with tight cell junctions
   b. well-developed CT and thick
   c. contains numerous longitudinally-oriented smooth muscle cells
3. Tunica media  
   a. relatively thin layer compared to same layer in arteries  
   b. smooth muscle oriented circularly  

4. Tunica adventitia  
   a. thickest layer of the wall  
   b. contains longitudinally-oriented smooth muscle in dense irregular CT  
   c. smooth muscle strengthens wall and prevents its over distension  

V. Heart  

A. Endocardium - homologous to the tunica intima layer of blood vessels  
   1. Possesses a continuous endothelium with junctions and an underlying basement membrane  
   2. Subendothelial layer - contains small blood vessels and in specialized myocardial cells of the impulse-conducting system of the heart  
   3. Cardiac valves - folds of endocardium with a central flat sheet of dense CT - the latter continuous with the dense CT of the annuli fibrosi  
      a. semilunar valves - tricuspid valves in aortic and pulmonary trunks  
      b. atrio-ventricular valves - free borders connected to papillary muscles by chordae tendinæ  
      c. valves may be damaged by bacterial endocarditis - causes perforations
4. Cardiac skeleton - formed of dense irregular CT
   a. annuli fibrosi - rings surrounding each valve and continuous with CT of valve
   b. fibrous trigones - two triangular zones between annuli fibrosi
   c. septum membranaceum - forms the superior portion of the interventricular septum
   d. skeleton may be damaged in cases of rheumatic fever

B. Myocardium

1. Myocardium proper
   a. thinnest in atria and thickest in the left ventricle
   b. fibers insert on components of the cardiac skeleton
   c. muscle of atria and ventricles completely separate
   d. fibers may be injured by reduction in available oxygen (ischemia)
   e. muscle can not regenerate after injury, so scar tissue develops

2. Impulse-conducting system
   a. formed of specialized cardiac muscle cells that coordinate and regulate contractions of atrial and ventricular muscles
   b. sino-atrial node in endocardium of right atrium near the superior vena cava
   c. impulses pass from SA node fibers next to atrioventricular node in endocardium of right interatrial septum
   d. fibers then pass to atrioventricular bundle located within the septum membranaceum
   e. Purkinje fibers, impulses spread between cardiac muscle cells (in the myocardium) via intercalated Purkinge fibers - specific name for fibers which lie in the endocardium, connecting the SA & AV nodes, AV bundle and from the bundle to the myocardium - they appear larger and more vacuolated than normal cardiac muscle cells and conduct impulses much faster as well form discs

C. Epicardium - formed of dense irregular CT with adipocytes and visceral pericardium
Cardiovascular System - Laboratory Guide
Find the following among the images on the CD

Elastic Artery (Aorta)
- tunica intima
- tunica media
- elastic lamellae
- smooth muscle cells
- tunica adventitia
- vasa vasorum
- collagen bundles

Muscular Artery
- internal elastic lamina
- tunica intima
- tunica media
- smooth muscle cells
- collagen and elastic fibers
- external elastic lamina
- tunica adventitia
- vasa vasorum
- small nerve fibers

Transitional Artery
- tunica intima
- tunica media
- smooth muscle cells
- collagen and elastic fibers
- elastic lamellae
- tunica adventitia
- vasa vasorum

Microvasculature
- arterioles
- capillaries
- venules
- small veins
- lymphatic vessels
- valves

Capillaries
- continuous
- fenestrated
- discontinuous (sinusoid)

Inferior Vena Cava (Large Vein)
- tunica adventitia
- smooth muscle cells
- tunica media
- internal elastic lamina
- subendothelium of tunica intima
- tunica intima

Heart
- interventricular septum
  (muscular portion)
- septum membranaceum
- semilunar valve of the aorta
- atrioventricular valve
- endothelium
- annulus fibrosus
- endocardium
- aorta
- interatrial septum.
- atrioventricular bundle (of His)
- right and left bundle branches
- Purkinge fibers
- myocardium
- intercalated discs