Chapter 21
Peripheral circulation and Regulation

I. Blood vessel structure
   A. Blood flows from large arteries to small capillaries
      1. Large arteries contain large amounts of elastic tissue and little smooth muscle
      2. Small arteries contain large amounts of smooth muscle and little elastic tissue.
   B. Classification of arteries
      1. elastic arteries,
      2. muscular arteries and
      3. arterioles to capillaries
   C. Blood returns to the heart from the capillaries through
      1. venules,
      2. small veins and
      3. Medium to large veins.

II. Structure of Capillaries
   A. The entire circulatory system is lined with simple squamous epi called endothelium
   B. Capillaries consist of:
      1. endothelium,
      2. basement membrane and
      3. adventicia (loose C.T.)
   C. Three types of capillaries
      1. Continuous
         a. Do not have gaps (fenestra)
         b. Low permeability to large molecules.
         c. Diameter 7-9um
      2. Fenestrated
         a. Have pores called fenestra that extend completely through the cell
         b. Diameter 70 - 100 um
         c. Highly permeable
         d. Found in choroid plexus of CNS, glomerulus of kidney.
      3. Sinusoidal
         a. capillaries with larger fenestra than fenestrated
         b. Larger diameter than fenestrated
         c. Have little basement membrane.
         d. Found in endocrine glands, liver, spleen and bone marrow where large molecules must pass.
   D. Materials pass out of capillaries by:
      1. Passing between endothelial cells (small water soluble molecules)
      2. Through fenestra (lg water sol.)
      3. Through the cell membrane of endothelial cells.(lipids).
   E. Blood flow:
      1. Flow is from arterioles through metaarterioles and then through the capillary
network.
2. Venules drain the capillary network
3. Smooth muscle in arterioles, metaarterioles and precapillary sphincters regulate blood flow into the capillaries
4. Blood can pass rapidly through the thoroughfare channels or be routed through capillary beds depending on need.
5. Function: nutrient delivery and waste removal
   a. thermoregulation in skin and

III. Structure of arteries and veins.
A. Except capillaries and venules blood vessels have three layers
   1. Tunica intima
      a. Endothelium, basement membrane, lamina propria and internal elastic membrane.
   2. Tunica media
      a. Middle layer
      c. variable amounts of elastic and collagen fibers
      d. Vasoconstriction - smooth muscle constriction
      e. Vasodilation - smooth muscle relaxation.
   3. Tunica adventitia
      a. Connective tissue (dense to loose) contains fibroblasts

B. The thickness and composition of the layers vary with blood vessel type and diameter
   1. Elastic arteries (conducing arteries) are thin walled with large diameters
      a. High pressure
      b. Large amount of elastic fibers and little smooth muscle in tunica media.
      c. Extent of expansion is dictated by the collagen fibers of the adventitia
   2. Muscular arteries -
      a. thick walled compared to diameter
      b. Large: The tunica media has 25-40 layers of smooth muscle and some elastic fibers
      c. Medium and Small: Layers of smooth muscle gradually reduces to three or four layers
   3. Arterioles - smallest arteries
      a. Tunica intima has no internal elastic membrane.
      b. Tunica media consists of smooth muscle cells and few elastic fibers
      c. Capable of vasodilation and vasoconstriction.
      d. 40 um
   4. Venules - composed of endothelium with few smooth muscle cells
      a. 40-50 um
b. Similar structure to capillaries.
c. Endothelium rests on a delicate basement membrane.

5. Small veins
   a. Venules converged with a few smooth muscle cells
   b. 200-300um
   c. Nutrient exchange occurs

6. Medium sized veins and large veins -
   a. Contain less smooth muscle and
   b. Fewer elastic fibers than arteries of the same size
   c. Tunica media is small, tunica adventitia is large.

C. Valves
   1. Prevent backflow of blood in veins
   2. In veins greater than 2 mm.
   3. Consist of folds in the tunica intima

D. Vasa vasorum
   1. Blood vessels that supply the tunica adventitia and tunica media

E. Arteriovenous anastomoses
   1. Allow blood to flow from arteries to veins without passing through capillaries
   2. Function in temp reg
   3. Present in sole, palm and phalanges and nail bed.

F. Nerves
   1. Walls of blood vessels contain a rich supply of nerves.
      a. Primarily sympathetic nerve fibers
         (1) Response to stimulation is vasoconstriction.
      b. Parasympathetic.
         (1) Found in the penis and clitoris vasodilate.

G. Aging of the Arteries
   1. Arteriosclerosis - hardening of the arteries
      a. Thickening of the tunica intima and change in the elastic fibers making the
         tunica media less elastic.
   2. Atherosclerosis - deposition of material in the wall of the arteries to form plaques.
      a. Fatlike substance containing cholesterol
      b. Replaced later with collagen fibers and Ca++
      c. Lesion protrudes into the lumen of the arteriole.

IV. Dynamic of Blood Circulation
A. Laminar and Turbulent Flow in Vessels
   1. Blood flows in a streamlined layers called laminar flow.
   2. Turbulence occurs when blood passes a constriction, tight turn or rough surface.
   3. Common in heart and at bifurcations of vessels
   4. Abnormally constricted arteries increase the probability that thromboses will develop from the turbulent flow.

B. Blood Pressure
   1. BP is a measure of the force blood exerts against the body.
a. Measured with
   (1) a Mercury (Hg) monometer with a direct line into artery
   (2) sphygmomanometer and auscultation for Korotkoff sounds
b. Systolic vs Diastolic pressure

C. Blood Flow
   1. Rate - expressed as volume / min
      a. Cardiac output - approx. 5 L/min.
      b. Flow is proportional to the pressure difference between two points
         (1) Flow is always from a high pressure to a low pressure
   2. Flow is opposed by resistance ( 
      a. As resistance increase flow decreases. 
      b. Flow = \( \frac{P_1 - P_2}{R} \)

D. Poiseuille’s Law and factors that affect resistance.
   1. Other factors influence flow
      a. \[ \text{Flow} = \pi (P_1 - P_2) \frac{r^4}{8vl} \]
      b. Viscosity of blood = \( \nu \)
      c. Length of the vessel = \( l \)
      d. Pressure = \( P \)
      e. Radius of the blood vessel = \( r \)
      f. \textit{Note:} small changes in diameter of the vessel cause large changes in
         resistance and flow.
   2. During exercise changes in heart rate, strength of contraction and stroke volume
      contribute to large pressure changes. Peripheral vessels within muscle dilate to
      increase flow and decrease resistance.

E. Viscosity
   1. Viscosity is the measure of the resistance of a liquid to flow.
   2. The viscosity of blood can change dramatically due to dehydration or
      overproduction of blood cells.
   3. Increased viscosity increases workload on the heart significantly and can cause
      heart failure.

F. LaPlace’s Law
   1. \( F = D \times P \)
   2. \( F = \text{force}; D = \text{vessel diameter and } P = \text{pressure} \)
   3. As the diameter of a vessel increases the force applied to the wall increases even
      if pressure stays the same
   4. If part of a vessel wall becomes weakened and a bulge forms the force applied to
      the weakened portion of the wall increases.
   5. Aneurysms are bulges in vessel walls that are in danger of rupturing.
   6. Aneurysms in the brain or aorta can result in death.

G. Vascular Compliance
   1. Compliance is the tendency for blood vessel volume to increase as blood
      pressure increases.
   2. The more easily a vessel wall stretches the greater is its compliance.
   3. Venous compliance is 24 times greater than that of arteries.
a. Veins act as reservoirs for blood because their compliance allows them to hold much more blood than other areas of the vascular system.

V. Physiology of Systemic Circulation
A. The entire circulatory system functions to maintain adequate blood flow to all tissues.
   1. Most of the blood volume is in the veins, smaller volumes are in the arteries and capillaries.
B. Cross-Sectional Area of Blood Vessels
   1. The cross-sectional area of the capillaries is much greater than that of the arteries or major veins. Therefore the velocity of the blood is much slower in the capillary and much faster in both arteries and veins.
C. Pressure and Resistance
   1. Resistance in the arteries increases as the size decreases and is greatest at the small arterioles and capillaries.
   2. Resistance is low in the veins because of their relatively large diameter.
   3. Muscular arteries and arterioles are capable of constricting or dilating.
      a. Controlled by both autonomic and hormonal control
      b. Regulate flow to each region of the body.
D. Pulse Pressure
   1. PP = SP - DP (40mmHG = 120 - 80)
   2. Two major factors that affect PP are stroke volume and vascular compliance
   3. Aging causes a decrease in compliance causing a more rapid rise and fall of pressure thus increasing pulse pressure.
   4. Ejection of blood creates a pressure wave or pulse along the arteries.
      a. Pulse can be used to determine heart rate
      b. A weak pulse may indicate a decreased stroke volume.
E. Capillary Exchange and Regulation of Interstitial Fluid Volume
   1. Capillary exchange is the movement of substance into and out of the capillary.
      a. Nutrients, oxygen, CO2 and hormones must be exchanged.
   2. A net movement of fluid occurs from the blood into the tissues.
      a. Blood pressure, capillary permeability and osmosis affect movement of fluid from the capillaries.
      b. Net hydrostatic pressure in the capillary, pressure of the interstitial fluid and the osmotic pressure all contribute to movement.
   3. Changes in protein content in the blood or tissues as well as permeability changes in the vessels or localized damage to vessels that alters pressure can change the balance resulting in edema within the tissues.
   4. The fluid gained by the tissues is removed by the lymphatic system.
F. Functional Characteristics of Veins
   1. Venous return to the heart increases because of an increase in blood volume, venous tone, and arteriole dilation.
   2. Preload is determined by venous return
      a. Factors that affect venous return can greatly affect cardiac output (Starling law)
   3. Venous tone is the partial contraction of veins
      a. Sympathetic stimulation increases venous tone and thus increases venous
return and cardiac output.

4. Muscular contraction compresses veins thus increasing return to the heart
5. The combination of arterial dilation and muscular compression during exercise causes blood to return to the heart more rapidly than under resting conditions.

G. Blood Pressure and the Effect of Gravity
1. In a standing person, hydrostatic pressure caused by gravity increases blood pressure below the heart and decreases pressure above the heart.

VI. Control of Blood Flow by the Tissues
A. Local Control of Blood Flow by the Tissues
1. Regulation by the Metabolic needs of Tissues
   a. Vasodilator substances (CO2, lactic acid, adenosine, decrease pH, high K+) and some nutrients needed for metabolism (glucose, amino acids, etc.)
   b. Vasoconstrictor occurs as vasodilator substance are reduced.

B. Nervous and Hormonal Regulation of Local Circulation
1. Vasomotor center in the pons and upper medulla controls the level of vasoconstriction and maintain a level of vasomotor tone
   a. Norepinephrine released from sympathetic fibers acts on alpha adrenergic receptors to cause vasoconstriction but in muscular tissues it binds to the beta adrenergic receptor to cause vasodilation.
2. Constriction is caused by
   a. increased physical activity or sympathetic stimulation
   b. Decrease in body temperature detected at the hypothalamus.
3. Vasodilation is caused by:
   a. Increased body temperature detected by the hypothalamus
   b. Decrease in skin temperature beyond a critical point.
   c. Anger or embarrassment

VII. Regulation of Mean Arterial Pressure
A. Short-Term Regulation of Blood Pressure
1. Baroreceptor reflex
2. Adrenal Medullary Mechanism
3. Chemoreceptor Reflexes

B. Long-Term Regulation of Blood Pressure.
1. Renin-Angiotensin-Aldosterone Mechanism
   a. Renin is produced by the juxtaglomerular apparatus
2. Vasopressin (ADH) Mechanism
3. Atrial Natriuretic Mechanism
   a. Released in response to increased venous return which stretches the atria.
   b. Acts at kidney to increase urine production and thus reduce blood volume.
4. Fluid Shift Mechanism
   a. Interstitial fluid acts a reservoir to prevent the effects of extreme dehydration.
5. Stress-Relaxation Response
   a. As blood pressure drops vessels walls begin to constrict to resist a further drop in blood pressure.