Lecture 23: BLOOD VESSELS I

A Material Transport

1 Problem: Most body cells are not in direct contact with the environment, yet they need to exchange materials (nutrients, waste) with the environment. In addition, chemical messengers need to be sent from one part of body to another.

2 Vascular system brings blood to all cells; blood brings nutrients & messengers, and carries away waste

B Types of Blood Vessels & Their Features

1 Arteries

a high pressure

b elastic (smooth muscle surrounding)

2 Arterioles

a small artery reaches organ it supplies, and branches into numerous arterioles

b small radius (high resistance)

c regulates flow to tissue and overall blood pressure

3 Capillaries

a Arterioles further branch into

b Capillary exchange is whole point of circulatory

4 Venules

a Capillaries rejoin to form venules, carry blood back toward heart.

5 Veins

a stretchable

b storage (lowest pressure)

C Flow Rate: **the amount of blood that goes to each tissue**.

1 $F = \Delta P/R$ (for thinking of flow rate to each tissue)

a F = Flow Rate

b ΔP = pressure gradient

c R = resistance

2 **Pressure gradient**

a difference in pressure between beginning and end of a blood vessel

b blood flows down a pressure gradient, from high to low pressure.

c bigger the difference in pressure, the greater the flow

3 **Resistance**

a Measure of hindrance to blood flow

b As resistance increases, blood flow decreases

c Resistance determined by three factors

i **viscosity** = h (viscosity is friction that develops between molecules of a fluid as they bump into each other as the fluid flows).

ii **vessel length** = L

iii **vessel radius** = r

small change in radius has large impact on resistance

$R = 1/r^4$ doubling the radius decreases the resistance 16 times & therefore increases the flow rate 16-fold.

4 $F = \Delta P(r^4/8hL)$ B puts all these factors together in an equation (same as $F = \Delta P/R$)

II Arteries

A Act as rapid transit pathways from heart to tissues; offer **little resistance** to flow

B Act as a **pressure reservoir** to provide driving force for blood while heart is relaxing

III Arterioles: Function and Characteristics

A Have small radii, so **resistance is high** (highest in circulatory system).

B Control of arteriolar radius: Changing radii of arterioles is the major way to regulate blood flow to specific organs. (**Note: blood flow to brain is homeostatically maintained at constant level under all conditions**)

C Intrinsic (Local) Factors: Matching blood flow to metabolic needs of specific tissue

1 Local chemical influences

a **Local metabolic changes**: Increased metabolic demands of a tissue usually result in vasodilation & increased blood flow.

i Dilation of arterioles caused by:

Decreased O2

Increased CO2

Increased lactic acid

Increased extracellular K^+

ii Mechanism of local control: endothelial cells releasing local chemical messengers such as **nitric oxide (NO; which causes vasodilation)** and **endothelin (which causes vasoconstriction)**.

b Histamine release (causes vasodilation)

2 Local physical influences

a Temperature

D Extrinsic (Neural and Hormonal) Factors: Overall blood pressure regulation & local blood flow

1 Sympathetic (and hormonal) control

a At rest enough sympathetic activity to maintain Atone@

b Increased sympathetic activity (eg during exercise)

i **NE and epinephrine bind to alpha receptors and cause additional vasoconstriction** in most arterioles

ii In **heart and skeletal muscle, epinephrine binding to beta-2 receptors causes vasodilation**

iii bottom line: **reduced blood flow to most organs, but increased blood flow to skeletal muscle, heart, and skin**

iv In heart, skeletal muscle, and skin, **local control, especially those related to metabolic demands cause vasodilation of vessels**

2 Parasympathetic Control

no significant innervation of arterioles by parasympathetic NS

Lecture 24: BLOOD VESSELS II, BLOOD PRESSURE

I Capillaries

A Cellular Structure

1 Composed of a tube of a single layer of flattened endothelial cells

2 Capillary walls are very thin

3 Capillary lumen is so narrow (5 - 10 μm) that red blood cells (8 - 10 μm) have to squeeze through single file

4 Water-filled pores between epithelial cells in wall facilitate exchange. Big pores called fenestrations.

B Gross Structure: extensive capillary branching so that all cells in tissues not far from capillaries

1 Large overall surface area

2 Velocity of blood flow very slow in capillaries, allows time for exchange

a Don=t confuse flow rate (liters/minute) with velocity (mm/sec). Flow rate is always equal to cardiac output in all blood vessels; if blood is pumping 5 liters/minute, then every minute 5 liters of blood passes through arteries, arterioles, capillaries and veins.

C Function

1 Passive Diffusion

a Most important method of capillary exchange

b Diffusion occurs between capillaries and interstitial fluid, then between interstitial fluid and cells

c Lipid soluble substances (e.g., O_2 and CO_2; hydrophobic hormones) pass through endothelial cells by dissolving in lipid bilayer of membrane

d Small water soluble substances (ions, glucose, amino acids) pass through pores. Some protein, too, if pores are big enough.

2 Vesicular transport (minor)

a Endocytosis C through endothelial cell B exocytosis on other side

b Large proteins can be exchanged this way

3 Bulk Flow (filtration and reabsorption)

a Because capillaries have open pores, must consider pressure differences between inside and outside of capillaries

b Proteins in blood (= colloid), result in an osmotic force (water wants to move into blood), that nearly balances the forces due to pressure differences.

d Pressure differences forces fluid out of capillaries near arteriolar end (filtration) and forces fluid in near venular end (reabsorption).

e Bulk flow does not play a big role in exchange of materials

f Bulk flow is important in regulating fluid exchange/balance between plasma and interstitial fluid.

E Control

1 Capillaries have no smooth muscle can not regulate blood flow

2 In some tissues, spiraling smooth muscle cells, called precapillary sphincters, surround arteriolar vessels just before capillaries.

3 Precapillary sphincters can contract and relax & so control blood flow into capillaries; these sphincters are regulated by the same local factors that influence arteriolar radius.

Veins

A Function

1 **Low resistance** passageways to return blood to heart

2 Serve as **capacitance (storage) vessels**

a have thin, stretchable but not elastic walls

b can distend to accommodate lots of blood

c Under resting conditions, ~60% of blood is in veins

B Venous Return

1 Veins influence cardiac output by changing the extent of venous return (how much blood enters each atrium/minute)

2 Factors influencing venous return

a Sympathetic activity: causes venous vasoconstriction which causes higher venous return.

b Skeletal muscle activity: increases venous return. Also counteracts the effects of gravity

c Venous valves: one-way valves in veins prevent backflow of blood away from heart

d Respiratory activity: Pressure within chest cavity is 4 mm Hg less than rest of body because of respiratory activity. This adds to pressure gradient difference between limbs and chest cavity

III Arterial Blood Pressure

A Regulating arterial blood pressure

1 **Mean Arterial Pressure** (measured as mentioned above), but is actually a function of **Cardiac Output** X **Total**

Peripheral Resistance; BP = CO X PR

2 How blood pressure regulated: Baroreceptor reflex: <u>purpose is to make sure BRAIN has adequate blood flow</u>

a baroreceptors located in the aorta and carotid arteries

b they are the Asensors@ in the baroreceptor reflex; they sense mean arterial pressure

c afferent neurons bring information to the integrating center in the brainstem

d efferent neurons (autonomic) innervate effector organs: arterioles (arterioles constrict, this increases total peripheral resistance, and so increases mean arterial pressure)

e effector organs also include: heart (cardiac output increases, and so increases mean arterial pressure)

B Measuring Blood Pressure

1 Pressure cuff is placed over artery in upper arm.

2 Assume measuring pressure in someone with arterial pressure of 120/80 mm Hg:

a When cuff pressure is above 120 (systolic pressure), cuff prevents blood flow through artery and no sound is heard

b When cuff pressure is between 120 and 80, blood flow is turbulent; intermittent sounds are heard

c When cuff pressure is below 80 (diastolic pressure), blood flows through normally and no sound is heard.

3 Difference between systolic and diastolic pressure is called pulse pressure; in this example is 40 mm Hg

4 Mean arterial pressure = diastolic pressure + 1/3 pulse pressure

a calculated this way because 2/3 of cardiac cycle is at diastole in a person at rest.

b In this example: 80 + (1/3) x 40 = 93 mm Hg

c It is mean arterial pressure which is regulated by blood pressure reflexes.

5 Because arteries offer little resistance to flow, arterial pressure is essentially the same throughout arterial tree

LYMPH AND BLOOD

Lymph System

A Problem: Under normal circumstances, slightly more fluid is filtered out of capillaries during bulk flow than is reabsorbed.
Solution: Lymph system

B Lymph System Structure

1 Vessels

a Smallest lymph vessels are called initial lymphatics; composed of overlapping endothelial cells

b Vessels progressively join together

c Vessels have one way valves to prevent backflow

2 Lymph vessels surrounded by smooth muscle which contracts & propels lymph forward

C Most important functions of lymph system

1 Return of excess filtered fluid

2 Defense against disease

a lymph percolates through lymph nodes on way back to venous system; lymph nodes contain specialized cells to destroy bacteria etc

function:

3 Transport of fat from GI tract

4 Return of filtered protein that gets out of capillaries but can=t get back in

II Blood composition

A Erythrocytes

B Leukocytes

C Platelets

D Plasma

III Plasma

A Composition:

1 90% water

2 1% inorganic ions (mostly Na+ and Cl-)

3 1% nutrients, waste, hormones, etc

4 8% plasma proteins (lipids are bound to proteins)

B Plasma Proteins

1 Albumin

2 Globulins

3 Fibrinogen

4 General Functions

4 General Functions

a osmotic regulation

b buffering

c carriers

d clotting

IV Erythrocytes (Red Blood Cells)

A Structure & Function

1 Flat, thin, disk shaped cells

a Gives large surface area for diffusion of O_2/CO_2

b Thinness allows rapid diffusion of O_2/CO_2

2 Membrane is flexible, allows cell to take odd shapes and squeeze through narrow openings

3 Each erythrocyte is essentially a bag of hemoglobin (no nucleus, organelles)

4 Hemoglobin

a composed of 4 subunits (protein)

b each subunit contains an iron-containing heme group; each heme group can bind one oxygen molecule; so a Hb molecule can carry 4 oxygen molecules

c can also carry CO_2 (transports back to lungs) (not of major importance)

5 Contain

a glycolytic enzymes for energy production

b carbonic anhydrase which converts CO_2 to bicarbonate (more on this later!)

6 Production & Destruction

a Each erythrocyte lasts about 4 months

b Most old erythrocytes removed by spleen

c New are produced by bone marrow in a process called erythropoiesis

d Production controlled by hormone erthrypoietin which is released by kidneys in response to low O_2 levels

V Body Defenses: Response and Repair of Damage

A Hemostasis: the arrest of bleeding from a broken blood vessel

1 Vascular spasm

a torn blood vessel constricts as inherent response to damage

b sympathetic activity increases and causes further constriction

c this initial "vascular spasm" causes sides of vessels to touch -- they are sticky and adhere to each other

2 Formation of a platelet plug

a platelets = cell fragments found in the blood; they are derived from megakaryocytes in bone marrow

b platelets are normally not likely to adhere to blood vessel wall

c but they stick to collagen

d causes release of ADP, which makes platelets to stick to each other

e normal, undamaged endothelium releases a potent aggregation inhibitor, this prevents the

aggregation reaction from continuing beyond the site of injury

3 Blood coagulation

3 Blood coagulation

a transformation of blood from liquid to solid

b final step is conversion of fibrinogen to fibrin; this fiberlike protein forms the meshwork of the clot

c catalyzed by thrombin

d initial step in blood vessels is due to exposed collagen or other foreign material

e alternative initial step (in tissues) is the release of factor III by damaged cells

f between the initial step(s) and the thrombin-catalyzed conversion of fibrinogen to fibrin, is a cascade of enzymatic steps; results in amplification of response

VI Inflammation

A Purpose: bring to the invaded area cells (immune system and repair) and plasma proteins (antibodies, clotting enzymes, etc.) that can

1 destroy the invaders

2 remove debris

3 prepare for healing and repair

B Release of histamine by mast cells

B Release of histamine by mast cells

1 increased capillary permeability to bring plasma proteins to invaded area

a plasma proteins outside of capillaries change the osmotic differences between capillary and interstitial fluid

b more water moves from capillary to interstitial fluid

c localized edema

2 increased vasodilation of arterioles in injured area

a increased blood supply to region

VII Repair of Injury/Scar Formation

A Clot is dissolved

1 clot is slowly dissolved by plasmin

2 inactive form is plasminogen

activated by several different things, including tissue plasminogen activator (tPA)

B Replacement of lost/damaged tissue

B Replacement of lost/damaged tissue

1 Fibroblasts (a proliferative, motile connective tissue cell type) accomplish much of the repair by secreting collagen, which forms scars

2 Lost tissue is usually replaced by the same type of tissue, except

a when injury is large or destroys multiple types of tissue

b when injury involves non-regenerative tissue

*neurons in CNS are replaced by glia (?)

*muscle cells can be replaced by satellite cells that develop into muscle fibers