Chapter 19
Blood Vessels
Lecture 4

Lecture Overview

• Arteries and arterioles

• Capillaries and capillary exchange

• Veins and venules

• Blood pressure and its regulation

Overview of Blood Vessels

• arteries
  • carry blood away from ventricles of heart

• arterioles
  • receive blood from arteries
  • carry blood to capillaries

• capillaries
  • sites of exchange of substances between blood and body cells

• venules
  • receive blood from capillaries

• veins
  • carry blood toward atria of heart

Know the function of each of these types of vessels
Overview of Blood Vessels

Note the absence of smooth muscle in capillaries.

We have about 60,000 miles of blood vessels in our bodies!

Figure from: Saladin, Anatomy & Physiology, McGraw Hill, 2007

Arteries and Arterioles

**Arteries**
- thick strong wall
- endothelial lining
- middle layer of smooth muscle and elastic tissue
- outer layer of connective tissue
- carries blood under relatively high pressure
- control blood flow into organs

**Arterioles**
- thinner wall than artery
- endothelial lining
- smooth muscle tissue
- small amount of connective tissue
- control blood flow into capillary beds

Comparison of Walls of Arteries and Veins

Smooth muscle of the tunica media in both arteries and veins is innervated by the sympathetic nervous system.

Figure from: Hole's Human A&P, 12th edition, 2010
Arteriole

- smallest arterioles only have a few smooth muscle fibers
- can vasoconstrict (decrease diameter) or vasodilate (increase diameter)

- Most important in controlling blood flow to capillary beds

Metarterioles

- Each metarteriole supplies about 10-100 capillary beds
- Metarterioles form arteriovenous shunts that can bypass capillary beds

Capillaries

- smallest diameter blood vessels (fit 1 RBC at a time)
- extensions of inner lining of arterioles
- walls consist of endothelium and basement membrane only – NO smooth muscle
- semipermeable (plasma fluid can escape, but not proteins)

- 3 types:
  - continuous (muscle)
  - fenestrated (endocrine glands, kidney, small intestine)
  - sinusoids (liver, spleen, bone marrow)
Capillary Network

Blood can follow different pathways through metabolically active/inactive tissues.

Figure from: Hole's Human A&P, 12th edition, 2010

Differences in Blood Flow: At Rest/Exercise

Figure from: Saladin, Anatomy & Physiology, McGraw Hill, 2007

Regulation of Capillary Blood Flow

Precapillary sphincters
- may close a capillary
- respond to needs of the cells
- low oxygen and nutrients cause sphincter to relax

Figure from: Hole's Human A&P, 12th edition, 2010
**Exchange in the Capillaries**

- Major mechanism involved in exchange of solutes is diffusion.
- Substances move in and out along the length of the capillaries according to their respective concentration gradients.
- Fluid movement in systemic capillaries is determined by two major factors:
  1. Hydrostatic pressure; varies along portions of capillaries.
  2. Osmotic pressure; remains about the same along the length of the capillary.

**Forces Acting Across Capillary Walls**

What would increase the net amount of fluid leaving the capillaries?

What would decrease the net amount of fluid leaving the capillaries?

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**Venules and Veins**

- **Venule**
  - Thinner wall than arteriole; larger lumen.
  - Less smooth muscle and elastic tissue than arteriole.

- **Vein**
  - Thinner wall than artery; larger lumen.
  - Three layers to wall but middle layer is poorly developed.
  - Some have flaps like valves.
  - Carries blood under relatively low pressure.
  - Serves as blood reservoir.
  - Are able to constrict (sympathetic innervation).
Venous Valves

Valves aid one-way blood flow since pressure is low in veins. If the walls of veins near valves become weakened, valves may fail, blood will pool, vessels will become distended, e.g., varicose veins.

Blood Volumes in Vessels

Important for control of blood pressure. At any one time, most of the body’s blood is in the venous system; thus they are a major factor influencing venous return to the heart.

Venous Blood Flow

- not just a direct result of heart action
- depends on skeletal muscle contraction (skeletal muscle pump)
- depends on breathing (respiratory pump)
- depends on venoconstriction
Some Blood Flow Preliminaries

- **Blood flow** is the volume of blood that flows through any tissue in a given amount of time
- **Total blood flow** = CO (ml/min)
- Two important factors influence how the CO gets distributed to the body
  - **Pressure** that drives the blood through a tissue
  - **Resistance** to blood flow (OPPOSES FLOW)
- **Blood Flow (CO) \propto \text{Pressure} / \text{Resistance}**

Vascular Resistance

- The **resistance to blood flow** (vascular resistance) is dependent upon several factors
  - Size of the lumen of the blood vessel \((R \propto 1/r^4)\)
    - Smaller lumen = more resistance to flow
    - Larger lumen = less resistance to flow
  - **Main physiological control of resistance and flow**
    - Blood viscosity (thickness) which is determined by the ratio of RBCs to plasma
    - Increased viscosity = more resistance to flow
  - **Total blood vessel length** (Let’s gain a few pounds; 200 MILES / pound of adipose!)
    - Longer total blood vessel length = more resistance to flow
  - **Turbulence** (increased turbulence = more resistance)

Recall: **Blood Flow (CO) \propto \text{Pressure} / \text{Resistance}**

Arterial Blood Pressure

- **Blood Pressure** – force the blood exerts against the inner walls of the blood vessels

  - **Arterial Blood Pressure**
    - rises when ventricles contract
    - falls when ventricles relax
    - **systolic pressure** – maximum pressure
    - **diastolic pressure** – minimum pressure

  - **Pulse pressure** = difference between systolic and diastolic pressures (systolic : diastolic : pulse pressure ~ 3:2:1)
    - Pulse pressures usually rise with age because of an increase in blood vessel (aortic) resistance (arteriosclerosis)

Recall: **Blood Flow (CO) \propto \text{Pressure} / \text{Resistance}**
Mean Arterial Pressure

Mean Arterial Pressure (MAP) – Average effective pressure driving blood flow through the systemic organs

\[ \text{MAP} = \text{CO} \times \text{Total Peripheral Resistance (TPR)} \]

**Thus ALL changes in MAP result from changes in either cardiac output or peripheral resistance**

- If CO increases, MAP?
- If TPR decreases, MAP?
- If TPR decreases, what must be done to keep MAP the same?
- If blood volume decreases, what must be done to keep MAP the same?

MAP can be estimated by the equation:

\[ \text{diastolic bp} + \left( \frac{\text{pulse pressure}}{3} \right) \]

(Roughly 1/3 of the way between systolic and diastolic pressures)

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Pulse

A ‘pulse’ is a rhythmic pressure wave accompanying each heartbeat.

- Temporal a.
- Carotid a.
- Facial a.
- Brachial a.
- Radial a.
- Femoral a.
- Popliteal a.
- Dorsalis pedis a.
- Posterior tibial a.

The alternate expanding and recoiling of the arterial wall that can be felt (palpated) easily at certain locations on the body

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Factors That Influence Arterial Blood Pressure

\[ \text{BP (MAP)} = \text{Cardiac output} \times \text{Peripheral Resistance} \]

- Blood volume increases
- Heart rate increases
- Stroke volume increases
- Blood pressure increases
- Blood viscosity increases
- Peripheral resistance increases
- Decrease in the above factors has the opposite effect, i.e., blood pressure decreases

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Know this!
Central Venous Pressure

- **Central Venous Pressure** = pressure in the vena cava near the right atrium (~2-4 mm Hg)
- Determines the filling pressure of the right ventricle
  - Determines the EDV of the right ventricle which
    - **Determines ventricular stroke volume (Frank-Starling)**
- Affects pressure within the peripheral veins
- Weakly beating heart causes an increase in central venous pressure (backup of blood)
- Increase in central venous pressure causes blood to back up into peripheral veins

Regulation of Blood Flow/Pressure

- Blood flow/pressure can be affected by
  1) Autoregulation
     - Local factors within tissue capillary beds
     - Cause localized reaction
  2) Neural mechanisms
     - Responses to changes in arterial pressure or blood gas levels (baroreceptors or chemoreceptors)
     - Cause more widespread changes
     - **Very rapid**
  3) Endocrine mechanisms (will be covered with endocrine/urinary systems)
     - Enhance short-term adjustments
     - Direct long-term changes
     - Work mainly through changes in blood volume

Autoregulation of Blood Flow/Pressure

- Local changes in response to metabolic needs of tissues
- Occurs at the level of the precapillary sphincters; not dependent on neural or hormonal mechanisms
- Changes in local blood flow may, or may not, necessitate activation of neural and/or hormonal mechanisms
Autoregulation of Blood Flow/Pressure

- Local vasodilators increase blood flow
  - Decreased O₂ (except pulmonary circulation) or increased CO₂
  - Increase in lactic acid production
  - Increased K⁺ or H⁺
  - Release of nitric oxide (NO)
  - Mediators of inflammation (histamine, NO)
  - Elevated local temperature
  - Some prostaglandins
- Local vasoconstrictors decrease blood flow
  - Thromboxanes (released by activated platelets and WBCs)
  - Endothelins released by damaged endothelial cells
  - Some prostaglandins

Neural Control of Blood Pressure

Controlling cardiac output and peripheral resistance regulates blood pressure

Know this!

Neural Control of Blood Pressure

If blood pressure rises, baroreceptors initiate the cardioinhibitory reflex, which lowers the blood pressure

Know this!
**Neural Control of Blood Pressure**

Dilating arterioles helps regulate (lower) blood pressure

- Rising blood pressure
- Stimulation of baroreceptors in aortic arch and carotid sinuses
- Sensory impulses to vasomotor center
- Vasomotor center inhibited
- Less frequent sympathetic impulses to arteriole walls
- Vasodilation of arterioles
- Decreased peripheral resistance
- Blood pressure returns toward normal

Know this!

Figure from: Hole’s Human A&P, 12th edition, 2010

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**Hormonal Control of Blood Pressure**

Changes blood pressure by changing the volume of the blood

Figure from: Martini, Anatomy & Physiology, Prentice Hall, 2001

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**Hormonal Control of Blood Pressure**

Changes blood pressure by changing the volume of the blood

Figure from: Martini, Anatomy & Physiology, Prentice Hall, 2001
Factors Affecting Blood Pressure (MAP)

MAP = Contractility x Afterload

Factors affecting heart rate

Factors affecting stroke volume

MAP (BP) = CVP

Factors affecting stroke volume

Factors affecting heart rate

Factors affecting blood pressure

Review

- The blood vessels form a closed circuit for distribution of the blood from the heart to the tissues and back again.
- The vessels of the CVS include
  - Arteries - carry blood away from ventricles of heart; this walled; elastic
  - Arterioles - receive blood from arteries/carry blood to capillaries; major flow regulators
  - Capillaries - sites of exchange of substances between blood and body cells
  - Venules - receive blood from capillaries
  - Veins - carry blood toward atria of heart
Review

• Capillary-tissue exchange is dependent upon
  – Diffusion (Exchange of solutes)
  – Osmosis (colloid osmotic pressure)
  – Filtration
  – Vesicular transport

Exchange of fluid

• Blood pressure
  – Is the force exerted on vessel walls by the blood
  – Is usually measured as arterial blood pressure
    • Systolic – maximum pressure during ventricular systole
    • Diastolic – minimum pressure during ventricular diastole
  – Pulse pressure = systolic – diastolic
  – Mean arterial pressure = CO X TPR

Review

• Factors influencing blood pressure
  – Cardiac output (CO)
  – Blood volume
  – Blood viscosity
  – Peripheral resistance (PR)

• Cardiovascular system function can be regulated by
  – Tissue autoregulation
  – Neural mechanisms
  – Endocrine mechanisms

Review

• Veins are a large reservoir of blood and exert a large effect upon blood pressure

• Venous blood flow depends upon
  – Skeletal muscle contraction
  – Breathing movement
  – Vasoconstriction of veins (venoconstriction)

• Central venous pressure is the pressure near the right atrium
  – If CVP increases, blood may back up
  – Increased CVP can lead to edema