Chapter 14 The Cardiovascular System: Blood Vessels, Blood Flow and Blood Pressure (II)

Chapter Outline
- Capillaries and Venules
- Veins
- The Lymphatic System
- Mean Arterial Pressure and Its Regulation
- Other Cardiovascular Regulatory Processes

14.5 Capillaries and Venules

- **Structure**
  - 5–10 mm diameter—small diffusion distance
  - One cell layer thin wall, therefore small diffusion barrier

- **Function**
  - Primary site of ____________between blood and tissue

- **Vessel Area and Velocity of Blood (Figure 14.15)**
  - Capillaries have greatest total cross-sectional area
  - Have slowest velocity of blood flow, enhances exchange

- **Types of Capillaries**
  - **Continuous capillaries** are most common. They have small gaps between endothelial cells which allows small water soluble molecules to move through
  - **Fenestrated capillary** allow proteins and blood cells to move through.

- **Local Control of Blood Flow through Capillary Beds**
  - The materials exchange between the capillary and the tissue is regulated by the blood flow through the capillary bed.
  - Local control of smooth muscle in microcirculation (Figure 14.17)
    - Arterioles
    - *Metarterioles* function as shunts to bypass capillaries. They have rings of smooth muscle at strategic locations. They contract and relax in response to local factors
    - *Precapillary Sphincters* have rings of smooth muscle that surround capillaries on the arteriole end. They contract and relax in response to local factors only. The metabolites may cause relaxation

- **Movement of Material across Capillary Walls (Figure 14.18)**
  - Exchange of material between blood and cells
  - Bulk flow of fluid to distribute extracellular fluid

- **Capillary Exchange Mechanisms**
  - Most common: ____________
  - Exchange of protein: ____________
  - In brain: ____________
• **Bulk Flow of Fluid across Capillary Wall (Figure 14.19)**
  o Bulk flow = movement of water and solutes
  o Across capillary—protein free plasma moves
    - movement out of capillary
    - movement into capillary
  o Purpose—distribute ECF

• **Movement of Fluid across Capillary Walls**
  o Bulk flow is driven by net filtration pressure (____) which depends on the Starling forces
  o _______ = filtration pressure – absorption pressure = (P_{CAP} + \pi_{IF}) – (\pi_{CAP} + P_{IF})
  o Net filtration = 3 L/day
  o Lymphatic system picks up excess filtrate and returns it to circulation

• **Starling Forces across Capillaries (Table 14.3)**

<table>
<thead>
<tr>
<th>Force</th>
<th>Definition</th>
<th>Direction of force (filtration or absorption)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_{CAP}</td>
<td>Hydrostatic pressure exerted by the present of fluid inside of the capillary</td>
<td></td>
</tr>
<tr>
<td>\pi_{CAP}</td>
<td>Osmotic force due to presence of proteins in plasma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Osmotic force due to presence of proteins in interstitial fluid</td>
<td></td>
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</tbody>
</table>

• Figure 14.19 b
  o At arteriole end, NFP > _______; therefore _____________ occurs.
  o At venule end, NFP< _______; therefore _____________ is favored.

• **Factors Affecting Filtration and Absorption across Capillaries**
  o Factors promote filtration and edema(edema = swelling)
    - Standing on feet—increases hydrostatic pressure
    - Certain injuries
    - Capillaries damaged and leak fluid and proteins
    - Histamine increases capillary permeability to proteins

• **Factors Affecting Filtration and Absorption across Capillaries**
  o Liver disease: Decrease in plasma proteins
  o Kidney disease: Increase blood volume, and thus blood pressure; decrease in plasma proteins
  o Heart disease: Pulmonary edema
    - Cardiogenic causes of pulmonary edema results from high pressure in the blood vessels of the lung due to poor heart pumping function lead to accumulation of more than the usual amount of blood in the blood vessels of the lungs. The fluid to be pushed through the capillary walls into the air sacs.

**14.6 Veins**
- High compliance and function as a blood _____________ (Figure 14.21)
- Valves allow unidirectional blood flow
  - Present in peripheral veins
• Absent from central veins

**Factors that Influence Venous Pressure and Venous Return**

- The driving force of venous return is the pressure gradient between the veins and the right atrium
- A decrease in venous pressure → decreases driving force for venous return → decreases end-diastolic volume → decreases stroke volume → decreases cardiac output → decreases blood flow to organs

**Four Factors That Influence Venous Pressure and Venous Return**

- **Skeletal Muscle Pump (Figure 14.22):** One-way valves in peripheral veins, muscle contraction push blood forward
- **Respiratory Pump**
  - Inspiration: Decrease P in thoracic cavity and increase P abdominal cavity. This creates gradient that favors blood movement to thoracic cavity. Increased venous pressure → increased venous return
  - Expiration: Increased P in thoracic cavity increases venous return
- **Blood Volume**
  - Increase blood volume → increase venous pressure
  - Decrease blood volume → decrease venous pressure
  - Long-term regulation of blood pressure is through regulation of blood volume
- **Venomotor Tone**
  - Smooth muscle tension in the veins (regulated by sympathetic nerve)
  - Increase venomotor tone → increase venous pressure and decrease venous compliance → increase SV → increase CO

**Summary of Factors Affecting Venous Pressure and MAP (Figure 14.23)**

**14.7 The Lymphatic System (Figure 14.24)**

- System of vessels, lymph, nodes, and organs
- Functions
  - Return excess filtrate to circulation
  - Immune: Lymph nodes contain macrophages and filter lymph flowing through the node

**14.8 Mean Arterial Pressure and Its Regulation**

- MAP is determined by HR, SV and TPR
  - Calculations: MAP = CO x TPR; CO = HR x SV  Therefore: MAP = HR x SV x TPR

**Importance of MAP Regulation**

- Regulating MAP critical to normal function
- MAP < normal
  - Hypotension <90 mmHg/ 60 mmHg
  - Inadequate blood flow to tissues
- MAP > normal
  - Hypertension >120 mmHg/>80 mmHg
  - Stressor for heart and blood vessels
• **Extrinsic Control of Arteriole Radius and MAP**
  o Extrinsic control = control from outside of organ
  o MAP regulated through control of the heart (CO) and arterioles and veins (TPR)
    ▪ Neural control
    ▪ Hormonal control

• **Short and Long-Term Regulation of MAP**
  o Short-term regulation—seconds to minutes
    ▪ Regulate cardiac output and total peripheral resistance
    ▪ Involves heart and blood vessels
    ▪ Primarily neural control
  o Long-term regulation—minutes to days
    ▪ Regulate blood volume
    ▪ Involves kidneys
    ▪ Primarily hormonal control

• **Neural Control of MAP**
  o Negative feedback loops
  o Detector = baroreceptors
  o Integration Center = cardiovascular centers in the brainstem
  o Controllers = autonomic nervous system
  o Effectors = heart and blood vessels

• **Arterial Baroreceptors (Figure 14.26)**
  o Locations
    ▪ Arch
    ▪ Sinuses
  o Baroreceptors = pressure receptor, sometimes called stretch receptors.
    ▪ Respond to stretching due to pressure changes in arteries
    ▪ Arterial baroreceptors = sinoaortic receptors

• **Baroreceptors and Blood Pressure (Figure 14.27)**
  o Increased pressure ↑ AP frequency

• **Neural Pathway (Figure 14.28)**
  o Input
    ▪ Arterial baroreceptors
    ▪ Low pressure baroreceptors
    ▪ Chemoreceptors
    ▪ Proprioceptors
    ▪ Higher brain centers
  o Cardiovascular Control Center
    ▪ Medulla oblongata
    ▪ Integration center for blood pressure regulation
  o Output
    ▪ Sympathetic nerve system
    ▪ Parasympathetic nerve system

• **Baroreceptor Reflex (Figure 14.29)**

• **Example of the Baroreceptor Reflex in Action: Hemorrhage (Figure 14.30)**
  o Hemorrhage → ↓ Blood volume → ↓ MAP ← trigger baroreceptor reflex → ↑ sympathetic activity and ↓ parasympathetic activity → reflex compensation
Hemorrhage and Blood Flow
- Baroreceptor reflex
  - GI tract: ↑ resistance ↓ blood flow
  - Brain: Vasculature not subject of extrinsic control and no change in resistance
  - Blood diverted from GI tract to brain

Hormonal Control of MAP
- Arterial baroreceptors also regulate the secretion of the following hormones to work with the ANS
  - Epinephrine (adrenaline)
  - Vasopressin (ADH)
  - Angiotensin II

Factors involved in Extrinsic Control of MAP (Table 14.4)
Control of BP by Low-Pressure Baroreceptors
- Low pressure baroreceptors = volume receptors
  - Location: Walls of large systemic _____ and walls of the _______
- Decrease in blood volume activates receptors triggering responses that act in parallel with baroreceptor reflex

14.9 Other Cardiovascular Regulatory Processes
- Respiratory sinus arrhythmia
- Chemoreceptor reflexes
- Thermoregulatory responses
- Responses to exercise

Respiratory Sinus Arrhythmia
- During inspiration: ↑ sympathetic activity → ↑ HR
- During expiration: ↑ parasympathetic activity → ↓ HR

Chemoreceptor Reflexes
- Chemoreceptors respond to increases in CO₂ levels in blood
- Primary function: regulate blood CO₂ levels
- Effects on ventilation
  - Increases CO₂, which in turn increases TPR and decreases HR
  - Generally results in increased MAP

Thermoregulatory Responses
- Increase body temperature
  - Decrease sympathetic activity to skin
  - Vasodilation to skin
  - Increase heat loss to environment
- Thermoregulation takes precedence over the baroreceptor reflex
- Possible consequence: decreased TPR → decreased MAP

Independent Regulation of Blood Flow during Exercise
Understanding Exercise Cardiovascular Responses to Light Exercise: Figure 14.21a–b