Lecture Outline for Integrated Basic Health Sciences for Pharmacy

Physiology Component of Module : Cardiovascular 2

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Control of Blood Pressure

- *Short-term neural and hormonal controls*
  - Counteract fluctuations in blood pressure by altering peripheral resistance
- *Long-term renal regulation*
  - Counteracts fluctuations in blood pressure by altering blood volume

Short-Term Mechanisms: Neural Controls

- *Neural controls of peripheral resistance*
  - Maintain MAP by altering blood vessel diameter
  - Alter blood distribution in response to specific demands
- *Neural controls operate via reflex arcs that involve*
  - Baroreceptors
  - Vasomotor centers and vasomotor fibers
  - Vascular smooth muscle

The Vasomotor Center

- *A cluster of sympathetic neurons in the medulla that oversee changes in blood vessel diameter*
- *Part of the cardiovascular center, along with the cardiac centers*
- *Maintains vasomotor tone (moderate constriction of arterioles)*
- *Receives inputs from baroreceptors, chemoreceptors, and higher brain centers*

Short-Term Mechanisms: Baroreceptor-Initiated Reflexes

- *Baroreceptors are located in*
  - Carotid sinuses
  - Aortic arch
  - Walls of large arteries of the neck and thorax
- *Increased blood pressure stimulates baroreceptors to increase input to the vasomotor center*
  - Inhibits the vasomotor center, causing arteriole dilation and venodilation
  - Stimulates the cardioinhibitory center

- *Baroreceptors taking part in the carotid sinus reflex protect the blood supply to the brain*
- *Baroreceptors taking part in the aortic reflex help maintain adequate blood pressure in the systemic circuit*

Short-Term Mechanisms:
Chemoreceptor-Initiated Reflexes

- *Chemoreceptors are located in the*
  - Carotid sinus
  - Aortic arch
  - Large arteries of the neck
  - Chemoreceptors respond to rise in CO_2, drop in pH or O_2
  - Increase blood pressure via the vasomotor center and the cardioacceleratory center
- *Are more important in the regulation of respiratory rate (Chapter 22)*

Influence of Higher Brain Centers

- *Reflexes that regulate BP are integrated in the medulla*
- *Higher brain centers (cortex and hypothalamus) can modify BP via relays to medullary centers*

Short-Term Mechanisms: Hormonal Controls

- *Adrenal medulla hormones norepinephrine (NE) and epinephrine cause generalized vasoconstriction and increase cardiac output*
- *Angiotensin II, generated by kidney release of renin, causes vasoconstriction*
- *Atrial natriuretic peptide causes blood volume and blood pressure to decline, causes generalized vasodilation*
- *Antidiuretic hormone (ADH)(vasopressin) causes intense vasoconstriction in cases of extremely low BP*

Long-Term Mechanisms: Renal Regulation

- *Baroreceptors quickly adapt to chronic high or low BP*
- *Long-term mechanisms step in to control BP by altering blood volume*
- *Kidneys act directly and indirectly to regulate arterial blood pressure*

1. Direct renal mechanism
2. Indirect renal (renin-angiotensin) mechanism

Direct Renal Mechanism

- *Alters blood volume independently of hormones*
  - Increased BP or blood volume causes the kidneys to eliminate more urine, thus reducing BP
  - Decreased BP or blood volume causes the kidneys to conserve water, and BP rises

Indirect Mechanism

- *The renin-angiotensin mechanism*
  - ↓ Arterial blood pressure → release of renin
  - Renin→ production of angiotensin II
  - Angiotensin II is a potent vasoconstrictor
  - Angiotensin II → aldosterone secretion
    - Aldosterone → renal reabsorption of Na^+ and ↓ urine formation
  - Angiotensin II stimulates ADH release

Monitoring Circulatory Efficiency

- *Vital signs: pulse and blood pressure, along with respiratory rate and body temperature*
- *Pulse: pressure wave caused by the expansion and recoil of arteries*
- *Radial pulse (taken at the wrist) routinely used*

Measuring Blood Pressure

- *Systemic arterial BP*
  - Measured indirectly by the auscultatory method using a sphygmomanometer
  - Pressure is increased in the cuff until it exceeds systolic pressure in the brachial artery

Measuring Blood Pressure

- *Pressure is released slowly and the examiner listens for sounds of Korotkoff with a stethoscope*
- *Sounds first occur as blood starts to spurt through the artery (systolic pressure, normally 110–140 mm Hg)*
- *Sounds disappear when the artery is no longer constricted and blood is flowing freely (diastolic pressure, normally 70–80 mm Hg)*

Variations in Blood Pressure

- *Blood pressure cycles over a 24-hour period*
- *BP peaks in the morning due to levels of hormones*
- *Age, sex, weight, race, mood, and posture may vary BP*

Alterations in Blood Pressure

- *Hypotension: low blood pressure*
  - Systolic pressure below 100 mm Hg
  - Often associated with long life and lack of cardiovascular illness

Homeostatic Imbalance: Hypotension

- *Orthostatic hypotension: temporary low BP and dizziness when suddenly rising from a sitting or reclining position*
- *Chronic hypotension: hint of poor nutrition and warning sign for Addison's disease or hypothyroidism*

- *Acute hypotension: important sign of circulatory shock*

Alterations in Blood Pressure

- *Hypertension: high blood pressure*
  - Sustained elevated arterial pressure of 140/90 or higher
    - May be transient adaptations during fever, physical exertion, and emotional upset
    - Often persistent in obese people

Homeostatic Imbalance: Hypertension

- *Prolonged hypertension is a major cause of heart failure, vascular disease, renal failure, and stroke*
- *Primary or essential hypertension*
  - 90% of hypertensive conditions
  - Due to several risk factors including heredity, diet, obesity, age, stress, diabetes mellitus, and smoking

Homeostatic Imbalance: Hypertension

- *Secondary hypertension is less common*
  - Due to identifiable disorders, including kidney disease, arteriosclerosis, and endocrine disorders such as hyperthyroidism and Cushing's syndrome

Blood Flow Through Body Tissues

- *Blood flow (tissue perfusion) is involved in*
  - Delivery of O_2 and nutrients to, and removal of wastes from, tissue cells
  - Gas exchange (lungs)
  - Absorption of nutrients (digestive tract)
  - Urine formation (kidneys)
- *Rate of flow is precisely the right amount to provide for proper function*

Velocity of Blood Flow

- *Changes as it travels through the systemic circulation*
- *Is inversely related to the total cross-sectional area*
- *Is fastest in the aorta, slowest in the capillaries, increases again in veins*
- *Slow capillary flow allows adequate time for exchange between blood and tissues*

Autoregulation

- *Automatic adjustment of blood flow to each tissue in proportion to its requirements at any given point in time*
- *Is controlled intrinsically by modifying the diameter of local arterioles feeding the capillaries*
- *Is independent of MAP, which is controlled as needed to maintain constant pressure*

Autoregulation

- *Two types of autoregulation*

1. Metabolic

2. Myogenic

Metabolic Controls

- *Vasodilation of arterioles and relaxation of precapillary sphincters occur in response to*
  - Declining tissue O_2
  - Substances from metabolically active tissues (H^+, K^+, adenosine, and prostaglandins) and inflammatory chemicals

Metabolic Controls

- *Effects*
  - Relaxation of vascular smooth muscle
  - Release of NO from vascular endothelial cells
- *NO is the major factor causing vasodilation*
- *Vasoconstriction is due to sympathetic stimulation and endothelins*

Myogenic Controls

- *Myogenic responses of vascular smooth muscle keep tissue perfusion constant despite most fluctuations in systemic pressure*
- *Passive stretch (increased intravascular pressure) promotes increased tone and vasoconstriction*
- *Reduced stretch promotes vasodilation and increases blood flow to the tissue*

Long-Term Autoregulation

- *Angiogenesis*
  - Occurs when short-term autoregulation cannot meet tissue nutrient requirements
  - The number of vessels to a region increases and existing vessels enlarge
  - Common in the heart when a coronary vessel is occluded, or throughout the body in people in high-altitude areas

Read : Blood Flow in Special Areas p 715-717

Blood Flow Through Capillaries

- *Vasomotion*
  - Slow and intermittent flow
  - Reflects the on/off opening and closing of precapillary sphincters

Capillary Exchange of Respiratory Gases and Nutrients

- *Diffusion of*
  - O_2 and nutrients from the blood to tissues
  - CO_2 and metabolic wastes from tissues to the blood
- *Lipid-soluble molecules diffuse directly through endothelial membranes*
- *Water-soluble solutes pass through clefts and fenestrations*
- *Larger molecules, such as proteins, are actively transported in pinocytotic vesicles or caveolae*

Fluid Movements: Bulk Flow

- *Extremely important in determining relative fluid volumes in the blood and interstitial space*
- *Direction and amount of fluid flow depends on two opposing forces: hydrostatic and colloid osmotic pressures*

Hydrostatic Pressures

- *Capillary hydrostatic pressure (HP_c) (capillary blood pressure)*
  - Tends to force fluids through the capillary walls
  - Is greater at the arterial end (35 mm Hg) of a bed than at the venule end (17 mm Hg)
- *Interstitial fluid hydrostatic pressure (HP_{if})*
  - Usually assumed to be zero because of lymphatic vessels

Colloid Osmotic Pressures

- *Capillary colloid osmotic pressure (oncotic pressure) (OP_c)*
  - Created by nondiffusible plasma proteins, which draw water toward themselves
  - ~26 mm Hg
- *Interstitial fluid osmotic pressure (OP_{if})*
  - Low (~1 mm Hg) due to low protein content

Net Filtration Pressure (NFP)

- *NFP—comprises all the forces acting on a capillary bed*
- *NFP = (HP_c—HP_{if})—(OP_c—OP_{if})*
- *At the arterial end of a bed, hydrostatic forces dominate*
- *At the venous end, osmotic forces dominate*
- *Excess fluid is returned to the blood via the lymphatic system*

Circulatory Shock

- *Any condition in which*
  - Blood vessels are inadequately filled
  - Blood cannot circulate normally
- *Results in inadequate blood flow to meet tissue needs*

Circulatory Shock

- *Hypovolemic shock: results from large-scale blood loss*
- *Vascular shock: results from extreme vasodilation and decreased peripheral resistance*
- *Cardiogenic shock results when an inefficient heart cannot sustain adequate circulation*

END OF OUTLINE

References

Marieb, E. N. & Hoehn K (2010). Human Anatomy and Physiology. 8th Edition, Pearson, Benjamin Cummings.