Blood Pressure Regulation 2

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Objectives

- Outline the intermediate term and long term regulators of ABP.
- Describe the role of Epinephrine, Antidiuretic hormone (ADH), Renin-Angiotensin-Aldosterone and Atrial Natriuretic Peptide (ANP) in BP regulation
- Point out the role of Kidney-body fluid system in long term regulation of BP
- Follow up the responses of the circulatory shock
Factors affecting Total Peripheral Resistance

- Total peripheral resistance
  - Arteriolar radius
    - Local (intrinsic) control (local changes acting on arteriolar smooth muscle in the vicinity)
    - Extrinsinc control (important in regulation of blood pressure)
  - Blood viscosity
    - Number of red blood cells
    - Concentration of plasma proteins

- Major factors affecting arteriolar radius
  - Local metabolic changes in O₂, CO₂, other metabolites (important in matching blood flow with metabolic needs)
  - Sympathetic activity (exerts generalized vasoconstrictor effect)
  - Myogenic responses to stretch (play minor role in active and reactive hyperemia)
  - Heat, cold application (therapeutic use)
  - Histamine release (involved with injuries and allergic responses)
  - Vasopressin (hormone important in fluid balance; exerts vasoconstrictor effect)
  - Angiotensin II (hormone important in fluid balance; exerts vasoconstrictor effect)
  - Epinephrine and norepinephrine (hormones that generally reinforce sympathetic nervous system)
Nervous Control of the Heart

INPUT TO CARDIOVASCULAR CENTER (nerve impulses)
- From higher brain centers: cerebral cortex, limbic system, and hypothalamus
- From sensory receptors:
  - Proprioceptors—monitor movements
  - Chemoreceptors—monitor blood chemistry
  - Baroreceptors—monitor blood pressure

OUTPUT TO HEART (increased frequency of nerve impulses)
- Increased rate of spontaneous depolarization in SA node (and AV node) increases heart rate
- Increased contractility of atria and ventricles increases stroke volume
- Decreased rate of spontaneous depolarization in SA node (and AV node) decreases heart rate
Factors that affect the Mean Arterial Pressure

- Increased blood volume, as in water retention
  - Increased sympathetic impulses and catecholamines from adrenal medulla
    - Increased heart rate (HR)
      - Increased cardiac output (CO)
        - Increased mean arterial blood pressure (MABP)
  - Increased contraction of leg muscles (skeletal muscle pump)
    - Decreased parasympathetic impulses
      - Increased stroke volume (SV) (preload)
        - Increased cardiac output (CO)
          - Increased mean arterial blood pressure (MABP)
  - Respiratory pump
    - Increased venous return
      - Increased blood viscosity
        - Increased systemic vascular resistance (SVR)
          - Increased mean arterial blood pressure (MABP)
    - Increased ratio of red blood cells to blood plasma, as in polycythemia, dehydration, or burns
      - Increased total blood vessel length
        - Decreased blood vessel radius, as occurs with vasoconstriction
          - Increased mean arterial blood pressure (MABP)
    - Increased body size, as in obesity
Intermediate / Long term Regulation of BP

1. Epinephrine – Adrenal medulla system
   works as intermediate term needs ~ 10 min. to work causes vasoconstriction

2. ADH (vasopressin) system needs ~ 30 min to work causes vasoconstriction
Long term Regulation of BP...cont

3. Renin-Angiotensin-Aldosterone system ~ 1 hour to be effective

Angiotensinogen (14 a.a peptide) converted into Angiotensin I (10 a.a peptide) by Renin that come from afferent arteriolar cell, the angiotensin I is converted into angiotensin II (8 a.a peptide) by Angiotensin converting enzyme mainly in the lungs.

Angiotensin II (A II) is very potent vasoconstrictor. AII also stimulates aldosterone synthesis and secretion from the adrenal coretx (Zona glomerulosa), aldosterone increases Na\(^+\) reabsorption from the renal nephrone and so water. AII is also a positive inotropic agent.
Long term Regulation of BP …cont

4. Atrial Natriuretic peptide (ANP): An 28 a.a peptide released mainly from the Rt. Atrium in response to stretch. It causes increase in GFR so increase Na$^+$ and water. Its concentration decreases when BP is low and its concentration increases if BP is high, mainly due volume overload.
CNS Ischemic Response

- CNS Ischemic response is activated in response to cerebral ischemia.
- Reduced cerebral blood flow causes CO2 buildup which stimulates vasomotor center thereby increasing arterial pressure.
- CNS Ischemic response is one of the most powerful activators of the sympathetic vasoconstrictor system.
CNS Ischemic Response

- CNS Ischemic response is not activated until pressure falls below 60mmHg; greatest activation occurs at pressures of 15-20mmHg.
- Cushing reaction is a special type of CNS ischemic response.
- Prolonged CNS ischemia has a depressant effect on the vasomotor center.
Atrial and Pulmonary Artery Reflexes

- Low pressure receptors in atria and pulmonary arteries minimize arterial pressure changes in response to changes in blood volume.
- Increases in blood volume activates low pressure receptors which in turn lower arterial pressure.
- Activation of low pressure receptors enhances Na$^+$ and water by:
  - Decreasing rate of antidiuretic hormone
  - Increasing glomerular filtration rate
  - Decreasing Na$^+$ reabsorption

Blood Volume

Atrial Stretch

Renal Sympathetic Activity

Atrial Natriuretic Peptide

↑ Sodium & Water Excretion
Bainbridge Reflex

- Prevents damming of blood in veins atria and pulmonary circulation.
- Increase in atrial pressure increases heart rate.
- Stretch of atria sends signals to VMC via vagal afferents to increase heart rate and contractility.

![Diagram of Bainbridge Reflex]

**Atrial Stretch** → **Vagal Afferents** → **Vasomotor Center (vasoconstrictor)** → **Heart Rate Contractility**
Blood Pressure Regulation

- Mean Arterial Pressure (MAP) = 1/3 systolic pressure + 2/3 diastolic pressure

\[ CO = \frac{MAP}{TPR} \]

\[ MAP = CO \times TPR \]
Renal Body Fluid System for Long Term Arterial Pressure Control

- Plays a dominant role in long term pressure control.

- As extracellular fluid volume increases arterial pressure increases.

- The increase in arterial pressure causes the kidneys to lose Na and water which returns extracellular fluid volume to normal.
Pressure Natriuresis and Diuresis

- The effect of pressure to increase water excretion is called pressure diuresis.
- The effect of pressure to increase Na excretion is called pressure natriuresis.
Graphical Analysis of Renal Body Fluid Mechanism

- The major determinants of long-term arterial pressure control.
  - Based on renal function curve
  - Salt and water intake line
- Equilibrium point is where intake and output curves intersect.
- Renal body fluid feedback system has an infinite gain.
Failure of Total Peripheral Resistance to Elevate Long-term Arterial Pressure

- Changes in TPR does not affect long-term arterial pressure level.
- One must alter the renal function curve in order to have long-term changes in arterial pressure.
- Changing renal vascular resistance does lead to long-term changes in arterial pressure.
Sodium is a Major Determinant of ECFV

- As Na\(^+\) intake is increased; Na\(^+\) stimulates drinking, increased Na\(^+\) concentration stimulates thirst and ADH secretion.
- Changes in Na\(^+\) intake leads to changes in extracellular fluid volume (ECFV).
- ECFV is determined by the balance of Na\(^+\) intake and output.
Volume Loading Hypertension
Effect of ECFV on Arterial Pressure

- Increased extracellular fluid volume
- Increased blood volume
- Increased mean circulatory filling pressure
- Increased venous return of blood to the heart
- Increased cardiac output
- Autoregulation
- Increased total peripheral resistance
- Increased arterial pressure
Renin-Angiotensin System

- Renin is synthesized and stored in modified smooth muscle cells in afferent arterioles of the kidney.
- Renin is released in response to a fall in pressure.
- Renin acts on a substance called angiotensinogen to form a peptide called angiotensin I.
- AI is converted to AII by a converting enzyme located in the endothelial cells in the pulmonary circulation.
Actions of the Renin Angiotensin System

- Causes vasoconstriction
- Causes $\text{Na}^+$ retention by direct and indirect acts on the kidney
- Causes shift in renal function curve to right
Renin Angiotensin System: Effect of Na\(^+\) Intake

- RAS is important in maintaining a normal AP during changes in Na\(^+\) intake.
- As Na\(^+\) intake is increased, renin levels fall to near 0.
- As Na\(^+\) intake is decreased, renin levels increase significantly.
- RAS causes the Na\(^+\) loading renal function curve to be steep.
Adrenal Gland as the source of Aldosterone (cortex) and Epinephrine (medulla)
Juxtaglomerular Apparatus
Factors Which Decrease Renal Excretory Function and Increase Blood Pressure

- Angiotensin II
- Aldosterone
- Sympathetic nervous activity
- Endothelin
Factors Which Increase Renal Excretory Function and Reduce Blood Pressure

- Atrial natriuretic peptide
- Nitric oxide
- Dopamine
Determinants of Mean Arterial BP

Mean arterial blood pressure

1. Cardiac output
   - Heart rate
     - Parasympathetic activity
   - Sympathetic activity and epinephrine
     - Venous return
       - Blood volume
         - Passive bulk-flow fluid shifts between vascular and interstitial fluid compartments

2. Stroke volume
   - Sympathetic activity effect
     - Respiratory activity
   - Skeletal muscle activity

3. Total peripheral resistance
   - Arteriolar radius
     - Local metabolic control
     - Extrinsic vasoconstrictor control
     - Number of red blood cells
   - Blood viscosity

4. Vasopressin and angiotensin II
   - Vasopressin, renin-angiotensin-aldosterone system (chapters 14 and 15)

5. Salt and water balance
Negative Feedback Cycle of Elevated BP
Consequences and Compensations of Hemorrhage

- **Hemorrhage**
  - ↓ Blood volume
  - ↓ Venous return
  - ↓ Stroke volume
  - ↓ Cardiac output
  - ↓ Arterial pressure

1. ↓ Thirst
2. ↑ Vasopressin and renin-angiotensin-aldosterone
3. ↓ Capillary blood pressure
4. ↓ Parasympathetic activity to heart
5. ↑ Sympathetic activity to heart
6. ↑ Sympathetic activity to veins
7. ↑ Sympathetic activity to arterioles
8. ↑ Firing of baroreceptors (through cardiovascular center)
9. ↑ Heart rate
10. ↑ Venous return
11. ↑ Renal blood flow
12. ↑ Urine output
13. ↑ Plasma protein synthesis by liver
14. Fluid shift from interstitial fluid into plasma
15. ↓ Cardiac output
16. ↓ Stroke volume
17. ↓ Arterial pressure
18. ↑ Arterial pressure
19. ↑ Total peripheral resistance
20. ↑ Urine output
21. ↑ Red blood cells
22. ↑ Release of hormone that stimulates red blood cell production
23. Consequences
24. Compensations
Thank You