BLOOD PRESSURE- II

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Learning Objectives

By the end of the lecture, you should be able to:

• Enlist the factors regulating Blood Pressure.
• Explain the various parts of the vasomotor center.
• Appraise the importance of neural control of the circulation.
• Describe the various reflexes contributing to the short term regulation of Blood Pressure.
• Explain the role of baroreceptor reflex in BP regulation.
• Outline the significance of CNS Ischemic response.
We must remember that the muscular arteries and arterioles are capable of constricting or dilating in response to NT & hormones.

Sympathetic and Parasympathetic activity affect veins, arteries and heart to control Heart rate and force of contraction.
There are, thus, two determinants of Blood Pressure:

1. **CARDIAC OUTPUT**, &
2. Total peripheral resistance

(1) **short-term mechanisms.**

regulate blood vessel diameter, heart rate and contractility

(2) **long-term mechanisms.**

regulate blood volume

- **Blood Pressure = cardiac output \times peripheral resistance**
- Any change in cardiac output, blood volume or peripheral resistance will lead to a change in blood pressure.

There are, thus, 02 determinants of Blood Pressure:

1. CARDIAC OUTPUT, &
2. Total peripheral resistance
Neural control of Circulation & it’s importance

Why is Nervous Regulation called short-term regulation?

It is called short-term regulation for 02 reasons:

1. When the blood pressure is altered, nervous regulation brings the system back to normal within a few minutes.

2. Although very quick in action, however, it operates only for a short time and then adapts to the new pressure. Thus, the regulation it provides is short term only.
Located in the Medulla Oblongata, THE CARDIOVASCULAR CENTER contains 3 distinct areas: Cardio excitatory center, Cardio inhibitory & the Vasomotor Center. The higher centers (hypothalamus, reticular substance, motor cortex, cingulate gyrus) influence THE CARDIOVASCULAR CENTER.
**VASOMOTOR CENTER**

**Location:** bilaterally in the reticular substance of the medulla and the lower thirds of the pons.

It consists of a vasoconstrictor, a vasodilator area & a sensory area.

- **Vasoconstrictor area** excites the sympathetic NS and causes mostly vasoconstriction.
- **Vasodilator area** causes vasodilation by inhibiting the Vasoconstrictor area.
- **Sensory area** receives the information regarding BP and provides reflex control of many circulatory functions.
The vasomotor center gives output through the sympathetic & parasympathetic fibers.
VASOMOTOR NERVES
- Vasoconstrictor (sympathetic only)
- Vasodilator (parasympathetic & sympathetic)
A SIMPLIFIED FIGURE OF
THE SYMPATHETIC
NERVOUS SYSTEM
Sympathetic & parasympathetic neurons DO NOT exert equal and opposite effects on all target tissues!

1. Parasympathetic neurons innervate the heart and a small number of blood vessels, limiting their influence largely to the control of cardiac function.

2. Sympathetic neurons innervate the heart, blood vessels, adrenal glands, muscles, kidneys and other organs.
Sympathetic Fibers (adrenergic fibers) secrete Epinephrine & Nor-epinephrine & their receptors can be as follows:

**Alpha 1**
- Vasoconstriction
- Inc. Resistance & Inc BP

**Beta 1**
- Only in the Heart
- Inc. Contractility & force of contraction

**Beta 2**
- Vasodilatation
- Skeletal muscles
Thus, control of the CVS is regulated mainly by the activity of the sympathetic nerves, with a limited but important cardiac effect of the parasympathetic nerves.
What is Vasomotor Tone?

Vasomotor tone is the continuous discharge of impulses through the sympathetic (vasoconstrictor) fibers. Vasomotor tone plays an important role in regulating the pressure by producing a constant partial state of constriction of the blood vessels.

Vasomotor tone is also called sympathetic *vasoconstrictor tone* or *sympathetic tone*.

This is why sympathetic outflow beyond this tonic level causes more vasoconstriction, whereas withdrawing sympathetic tone causes less vasoconstriction, i.e. causes vasodilation.
Although most vascular beds are innervated by the sympathetic nerves, they are not equally responsive to changes in sympathetic neural activity.

In general, arterioles of the skin, muscle, renal and splanchnic circulation show robust constriction in response to sympathetic stimulation, whereas cerebral and coronary arterioles are less responsive.

What do you think is the purpose of this differential responsiveness to sympathetic stimulation?
The role of Adrenal Medulla
Reflex mechanisms for maintaining normal arterial pressure during short term regulation:
Short-Term Regulation

- Rapidly Acting Pressure Control Mechanisms, Acting Within Seconds or Minutes.

A. Baroreceptor reflexes (60 – 100 mmHg)
   - Change peripheral resistance, heart rate, and stroke volume in response to changes in blood pressure

B. Chemoreceptor reflexes (40 – 60 mmHg)
   - Sensory receptors sensitive to oxygen lack, carbon dioxide excess, and low pH levels of blood

C. Central Nervous System ischemic response (< 40 mmHg)
   - Results from severe decrease blood flow to the brain
Baroreceptor Reflex
LOCATION: these spray endings are located in 2 major arteries & named accordingly:
- Aortic baroreceptors (thru the Vagus nerve)
- Carotid baroreceptors (thru the Herring’s nerve to the Glossopharyngeal N.)

↓ BP → CV Center → Generalized Systemic response

And what will the **systemic response** be:

1. ↑ Heart Rate
3. Venoconstriction leading to ↑ VR → ↑ EDV → ↑ CO (acc. to Starling’s Law)
4. Generalized art. vasoconstriction → ↑ TPR

Arterial BP = CO X TPR
Role of Baroreceptors

Cardiovascular Reflex Center

- Set Point: Systemic BP = 90 mmHg
- Sympathetic
  - Heart (C.O)
  - Veins (VR)
  - Arteries (TPR)
- Parasympathetic

Higher Brain Centers

Baroreceptors
When there is a fall in BP, 03 major changes occurring simultaneously leading to increase in BP:

- **Arteriolar vasoconstriction**
  - \( \uparrow \text{TPR} \)
  - \( \uparrow \text{Arterial Pressure} \)

- **Constriction of the Veins**
  - \( \uparrow \text{vol. of blood in heart chambers} \)
  - \( \uparrow \text{HR and Inc. CO} \)
  - \( \uparrow \text{Arterial Pressure} \)

- **Direct stimulation of the heart by ANS**
  - \( \uparrow \text{HR} \)
  - \( \uparrow \text{Inc. Contraction} \)
  - Inc. blood volumes pumped out which leads to a rapid inc. in arterial pressure
In the water faucet analogy, we have turned on the water more & also squeezed the arterioles. *(Increasing the pressure in the segment b/w the faucet & the arterioles.)*
THE BARORECEPTOR REFLEX

Systemic BP = 90 mmHg

CARDIOVASCULAR REFLEX CENTER

1. VENOCONSTRICTION
2. MYOCARDIAL CONTRACTILITY
3. ARTERIOLE VASOCONSTRICTION
4. THRU THE BARORECEPTORS

HR
CO
SV
TPR

Arterial Blood Pressure

\[ \text{Arterial BP} = \text{CO} \times \text{TPR} \]

Frank-Starling Law

\[ \text{EDV} \]
Most vessels in the body are going to constrict whereas the vessels to the heart & skeletal muscle are going to dilate.

So, we are reducing blood flow to every organ/tissue of the body (GI Tract, kidneys, all non-essential organs) but increasing blood flow to the heart & skeletal muscles.
ALARM REACTION

During extreme fright and fear, the arterial pressure sometimes rises by as much as 75 to 100 mmHg within a few seconds. It is called the alarm reaction and it provides an increase in arterial pressure that can immediately supply blood to the muscles of the body that might need to respond instantly to enable flight from danger.
POINTS TO NOTE:

1. The aortic baroreceptors respond to 30 mmHg or higher while the carotid respond to 50 mmHg or higher.

2. The baroreceptors respond much more to a rapidly changing pressure than to a stationary pressure.

3. Because the baroreceptor system opposes either increase or decrease in arterial pressure, it is called a **Pressure Buffer system**, and the nerves from the baroreceptors are called **Buffer nerves**.

4. The baroreceptors quickly reset to the new value & thus, in long term regulation, require interaction with other systems.

5. Baroreceptors attenuate BP changes during changes in Body posture.
What happens when you stand up suddenly from a sitting or a lying position...

**Baroreceptor Reflex Chart**

- Stand up quickly
- BP falls in upper body

- **Aortic Arch**
- **Carotid Sinus**

- **Neutral Integration**

- **Nucleus Tractus Solitarius**
- **Medulla Oblongata**

- **Effectors**

- **Veins & Arterioles**
- **Heart Muscle**
- **SA node**

- Vasoconstriction
- Increased SV
- Increased HR

- Increased TPR
- Increased CO

**Increased BP = CO x TPR**
Other Reflexes:

1. Chemoreceptor Reflex (already done & will be repeated with Respiratory system)

2. Atrial Reflex *thru low-pressure receptors* (detect pressure changes in low pressure areas of circulation & not in the systemic circulation)
   - The Volume Reflex
   - The Bainbridge Reflex

3. Pulmonary Artery Reflex *thru low pressure receptors* (detect pressure changes in low pressure areas of circulation & not in the systemic circulation)

4. CNS Ischemic Response
ATRIAL REFLEXES

The Volume Reflex

↑ in Blood Volume

↓

Stretch of atria

+ Reflex dilation of afferent arterioles of kidneys

↓

Hypothalamus decreases secretion of ADH

↓

↑ filtration of kidneys + ↓ reabsorption of water (due to ADH)

↓

Increased urine volume

↓

Reduced blood volume

The Bainbridge Reflex

• Already done with Heart
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.

Also called the last-ditch stand!!

Cerebral Ischemia $\rightarrow$ CO$_2$ $\rightarrow$ Vasomotor Center $\rightarrow$ Sympathetic Activity $\rightarrow$ Arterial Pressure
Cushing Reaction

- Special type of CNS Ischemic Response
  
  Increased pressure of cerebrospinal fluid (cranial vault)
  
  Increase intracranial tension
  
  Compress whole brain & arteries in the brain
  
  Cuts off blood supply to brain
  
  CNS Ischemic Response initiated & arterial pressure rises
  
  Relieve brain ischemia
The effects of exercise on the systolic & diastolic blood pressures

**MILD TO MODERATE EXERCISE**
- Systolic BP increases, while Diastolic BP remains the same.
- Because of sympathetic stimulation, the cardiac output increases, which in turn increases the systolic BP, but no effect on diastolic BP.

**SEVERE OR HEAVY EXERCISE**
- Systolic BP increases further and Diastolic BP decreases.
- More sympathetic stimulation will increase the Systolic BP further and the Diastolic BP drops because of a net decrease in the total peripheral resistance due to the more vasodilatation effect on the arterioles supplying the exercising skeletal muscles than the vasoconstriction effect on the arterioles supplying the other tissues.
Main Factors Affecting Blood Pressure

- Blood volume
- Cardiac output
- Total peripheral resistance

- Heart rate
- Stroke volume
**BARORECEPTOR REFLEX - PHYSIOLOGY**

**Blood Pressure (Mean Arterial pressure)**
- Baroreceptor Reflex (fast)
- Renin-aldosterone-angiotensin system (slow)

**Key Physiologic Definitions**
- **Mean Arterial Pressure (MAP)**
  - Cardiac Output x Total Peripheral Resistance
- **Cardiac Output**
  - Stroke Volume x Heart Rate
- **Total Peripheral Resistance**
  - Arteriolar constrictions

**Acute hypotension (hemorrhage, orthostasis)**
- MAP
- Baroreceptor stretch
- Baroreceptor activity
- CN 9 & 10 firing
- Sympathetic firing
- Parasympathetic firing
- Contractility
- Stroke volume
- Venous constriction
- Venous return
- Arteriolar constriction
- Cardiac output
- Total Peripheral Resistance
- MAP to Normal (set-point)

**PARASYMPATHETIC**
- Glossopharyngeal nerve (CN 9)
- Vagus nerve (CN 10)
- Cardioinhibitory center
- Vasomotor area

**SYMPATHETIC**
- Arch of Aorta
- Heart
- Spinal cord
- Renin-Angiotensin-Aldosterone System
  - Slow mechanism
  - Adjust MAP via blood volume
  - Involves low-pressure baroreceptors and atrial stretch receptors