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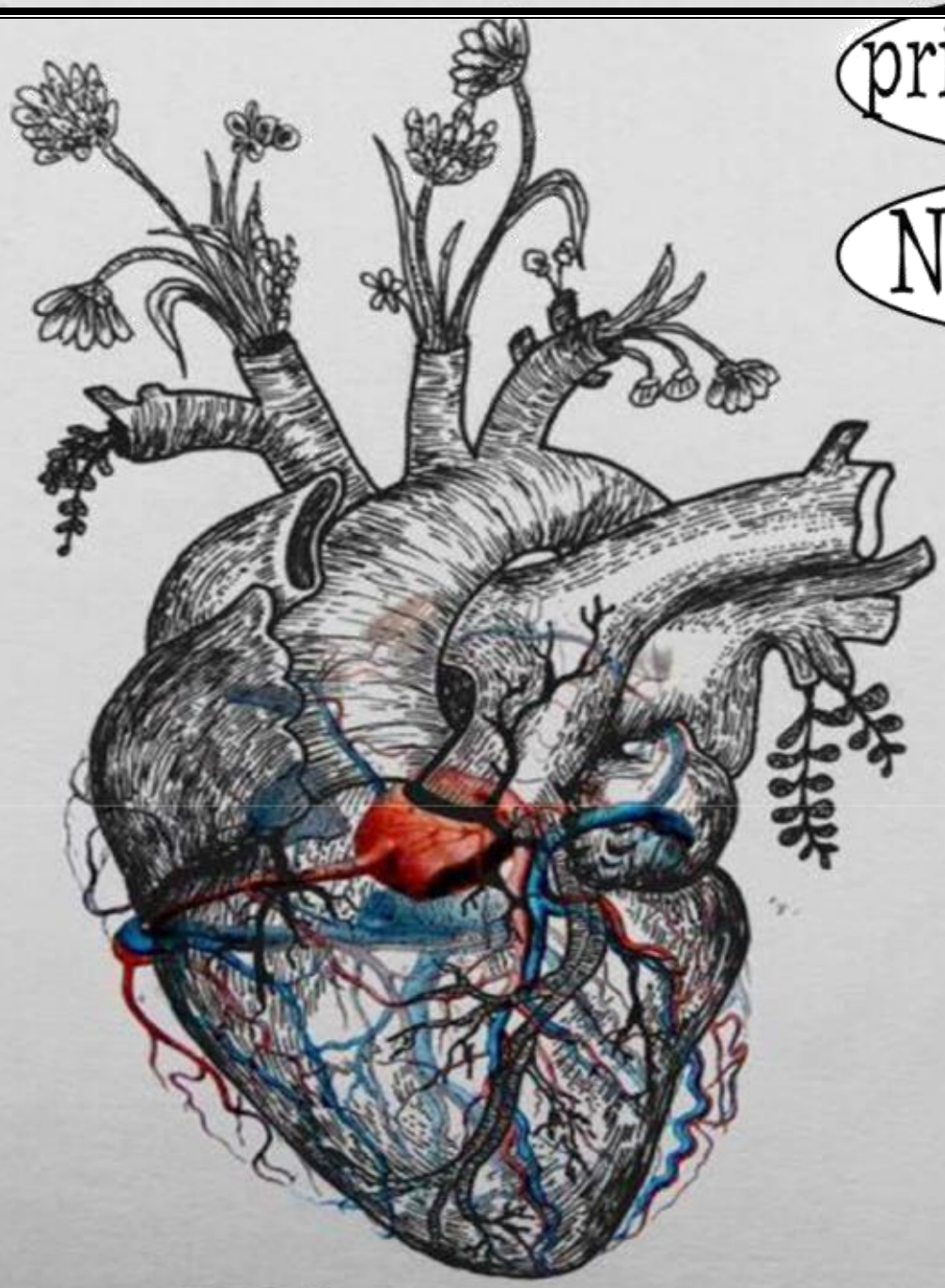

CVS

sub-system: Physiology #11

lecture: Regulation of blood pressure

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Date: Regulation30/3/2016ofblood pressure

Done by: Turquoise Team

Regulation of blood pressure

Introduction:

As we know from the previous lectures that if the systolic blood pressure of a person drops to 80 mmHg this person cannot stand up or walk, he must be in the hospital.

Also when someone stands up suddenly he will feel dizzy for a while, due to dropping down of the blood pressure in the brain.

(OverDose 2019) :

- This dropping down in the blood pressure we called it (postural hypotension) , in this time barrorecepters immediately (after fraction of second) sense the changing in the pressure and send a message to the brain … which will increase the total peripheral resistance or heart rate (cardiac output) .. or may be both of them ..

(P =F*R)

So there must be a mechanism to regulate the blood pressure to keep it in the normal range. As in regulation of blood flow to tissues, in blood pressure regulation: we have an **acute control** (for sudden changes of the blood pressure such as in anxiety) and a **long term control**.

Note: in this lecture we will talk about the acute control, long term control will be discussed in the next lecture.

So how does this regulation happen?

Actually there is 5 mechanisms for rapid control of blood pressure that will be discussed in this lecture.

I. Nervous system:

As we know that the nervous system is divided into sympathetic and parasympathetic nervous system. At normal situation the human body will be under sympathetic tone, so the blood pressure is under the regulation of sympathetic tone, this tone changes: it will increase in case of stress or anxiety and will decrease during resting or sleeping.

Sympathetic system innervates all parts of cardiovascular system up to pre-capillaries sphincter, so it regulates all parts except capillaries. Parasympathetic system is NOT involved in the regulation of blood pressure, but it only regulates SA node (so it only regulates the heart rate).

We all know that the sympathetic system will increase the heart rate and the parasympathetic system will decrease it, but how?

That is by controlling the permeability of the sodium and calcium ions through the cellular membrane.

The sympathetic system will increase the permeability of the membrane to increase the heart rate and the parasympathetic system will decrease the permeability of the membrane to reduce the heart rate.

The cardiovascular system has 3 ways to control the arterial pressure:

1.vasodilation. 2.vasoconstriction. 3.heart rate.

So to increase the blood pressure there must be vasoconstriction, increase in the heart rate (tachycardia) and increase in the contractility.

To decrease the blood pressure there must be vasodilatation, decrease in the heart rate (bradycardia) and decrease in the contractility.

For the nervous system to control the blood pressure there must be signals that can be translated into actions, these signals come from different sources like **baroreceptors (buffer system)**, **chemoreceptors**, **atrial and pulmonary artery reflexes (Bainbridge reflex)** and **CNS ischemic response**.

In the pons (which is located in the lower part of the medulla) there is a **vasomotor center** in the brain, this center is divided into 3 areas that are *vasodilator area* -that regulates vasodilation-, *vasoconstriction area* -that regulates vasoconstriction- and the *sensory area* -that regulate vasodilation, vasoconstriction and heart rate-.

(OverDose 2019) :

- Actually , it isn't a vasodilator area ,, it is working by make an inhibition in the sympathetic activity (sympathetic tone) . (it isn't working by making a vasodilatation directly).
- these parts is also controlled by higher nervous centers in the brain like (pons , mesencephalon and diencephalon) .

Vasomotor center receives the signals from the sympathetic nerves (mainly) and vagus nerve. So when the blood pressure decrease the signals go to the vasomotor center that understand that the blood pressure is low so the response goes to CVS to increase heart rate and to do a vasoconstriction and vice versa. And as we said these signals come from different sources such as **baroreceptors**.

Guyton says:

The neurons of this area "*sensory area"* receive sensory nerve signals from the circulatory system mainly through the *vagus* and *glossopharyngeal nerves*, and the output signals from this sensory area then help to control activities of both the vasoconstrictor and vasodilator areas of the vasomotor center, thus providing "reflex" control of many circulatory functions. An example is the baroreceptor reflex for controlling arterial pressure.

II. Baroreceptors (buffer system):

(baro- refers to barometer)

These receptors are sensitive to any change in blood pressure. And as we know, the normal blood pressure is 120 mmHg, so if the blood pressure rises to 122 or 123 mmHg there will be a response, also if the blood pressure goes down to 118 or 117 mmHg there will be a response.

They are called buffer system because they are sensitive to both side changes, either increase or

But if that happens, why people suffer from hypertension?

When the blood pressure increase (e.g.130 mmHg) in patients who have atherosclerosis (the vessels are rigid) the signals will go from the baroreceptors to the vasomotor center to cause vasodilatation, then vasomotor center will send signals to blood vessels to dilate, but blood vessels cannot dilate because they are rigid so the blood pressure will stay high, the signals will continue to go from baroreceptors for a day or two but then the baroreceptors will get fed-up)لمي او(and they will consider the new blood pressure (130 mmHg) as the normal value (so there will be resetting or adaptation) and they will respond according to the new value.

Normally blood pressure is 120 mmHg but with age it gradually increases by the age of 50 it could be 140 mmHg.

After another one or two years' blood pressure goes for a higher value (e.g.150 mmHg) so there will be signals again from the baroreceptors to vasomotor center and the center will send signals to the blood vessels but there will be no response because of the atherosclerosis so the baroreceptors will adapt themselves again to the new value (150

mmHg). So hypertension depends on the rigidity of the wall of the blood vessels, since when the rigidity increase, elasticity will decrease, that will reduce the ability of the blood vessels to dilate.

Vary important to remember that baroreceptors are **very sensitive** to any ***acute "transient"*** change of the blood pressure -e.g. In case of anxiety, the blood pressure will increase so there will be signals from the baroreceptors to vasomotor center to reduce the blood pressure so there will be vasodilation- **NOT** for long term -in case of sustained elevation of blood pressure "hypertension" they will reset themselves to that level of blood pressure-, that is why they cannot prevent the development of hypertension.

(OverDose 2019) :

- Q: How baroreceptors can sense the changing in the Blood pressure ?

1- When the blood flow to the receptors increased (BP↑) or decreased (BP↑) .
2- When there is an increasing in the blood pressure , it will stretch (which means an increasing in the Blood pressure) …. The SA node senses the changing in the R.A. size (Blood volume) by the same why .

- we called the Baroreceptors a (Buffer system) : that's meaning the action happens on two ways : (increases what decreases)and (decreases what increases) .

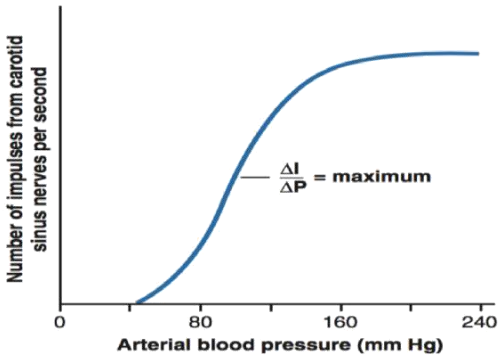
- Normally we have about 100 signals (from Baroreceptors) to the Brain , this number will increase when the Blood pressure increases , and it will decreased when the BP decreases … and the brain makes its response depending on this (sensitivity) .

- there is no signals when the blood pressure (0-60 mmhg) .

-when changing the position from standing to supine position : less vasoconstriction , less heart rate , less contractility . (and that's what we have when we sleep .)

- In the Autonomic nervous system (Sympathetic system) : we have :
1- alpha receptors : vasoconstriction .
2- Beta receptors : vasodilatation , many of them are found in the skeletal muscles , (this is what explains the vasodilatation in the exercise (and also the increasing in the heart rate and cardiac output .)
* Skeletal muscles : have some alpha (low number than beta) .
* Coronary arteries : Have some alpha and mainly beta (if the coronary constrict with the generalized sympathetic activity in the body , the heart will be under a danger of ischemic injury (and then MI) .)
* Heart : has alpha mainly and some beta receptors .

In normal situation when the blood pressure is 120 mmHg there will be hundreds of signals that go from the baroreceptors to vasomotor center to keep the blood pressure 120 mmHg, so if there is transient increase in the blood pressure these signals will be increased to decrease



the blood pressure. On the other hand, if the blood pressure decreases, the signals will be decreased so the vasomotor center will understand that the blood pressure is low, but when blood pressure reaches about 50-60 mmHg there will be **no** more signals going to the vasomotor center (that is an absolute **NO** signals that differs from feeding-up), so now vasomotor center will understand that the blood pressure is too low and it will response according to it, by doing a generalized vasoconstriction everywhere in the body to increase the peripheral resistant and increase the blood pressure that is called **CNS ischemic response** which will be discussed at the end of this sheet.

Student's questions:

What will happen if we solved the atherosclerosis problem? Practically we cannot solve this problem.

Hypertension is divided into primary (essential or idiopathic) that has an unknown cause -we consider hypertension that is obtained from atherosclerosis as primary hypertension because we cannot treat it - and the other one is the secondary hypertension that has a known cause that we can treat it -like renal artery stenosis that will cause an elevation in angiotensin, so the blood pressure will be elevated, we can treat it by dilatation of the renal artery so that will lower the angiotensin level -.

Theoretically, if we solved the atherosclerosis problem would the baroreceptors consider the new pressure value (150 mmHg) as a normal or there will be reset to the original value (120 mmHg)?

There will be a reset to the original value (120 mmHg) because the baroreceptors are very flexible.

Under normal situation if we had a vasodilation, the heart rate will increase as a compensatory mechanism, but will that happen in the case of hypertension too?

Always when the peripheral resistance is reduced, the cardiac output is supposed to increase, but while you are under stress the sympathetic stimulus will take time 'minutes' to be reduced because you are still thinking about the thing that caused your anxiety -but there will be a response-. So the vasomotor center will try to reduce the sympathetic tone but you are still under stress.

If we had hypotension the blood flow to the tissues will decrease, so wouldn't that cause vasodilation?

When the blood pressure drops, baroreceptors will send signals within fractions of a second to cause vasoconstriction, so the blood pressure will not stay low for long time it will change with any movement, so there will be NO change in blood flow to tissues. Also when the blood pressure increases "or decreases" to very high value vasomotor center will send order to get the blood pressure back to the normal value gradually (it will not go from 200 mmHg to 120 mmHg directly).

It is easy to understand that the blood pressure can be high but how can the blood pressure be low? Simply by **hemorrhage** (bleeding), also there is a case called ***vasovagal attack*** where there will be sever stimulation of the vagus nerve (parasympathetic). In this case you just have to put the patient on the floor and raise his legs to increase the venous return.

Vasovagal attack: occurs when you faint because your body overreacts to certain triggers, such as the sight of blood or extreme emotional stress. ~from google~

(OverDose 2019) :

- Some people when they know some abnormal expectations (suddenly) , the body will reduce the blood pressure significantly (a very strong stimulus on beta receptors) … which will lead to generalized vasodilatation ,,, that's what we called a vasovagal attack ,,, the patient will fell dizzy and can be lost in a short time .

In the book there are 2 pages talking about the anatomy of the brain and were the vasomotor center is located the doctor said that they are not important. You only have to know that there is a vasomotor center that is located in the medulla in the pons and that its function is controlling vasoconstriction, vasodilatation, heart rate and the contractility.

And you should understand the buffer system of the baroreceptors, and that they respond to any change in the blood pressure (increase or decrease), and there will be NO signals when the blood pressure is 60 mmHg, and the signals from baroreceptors increase when the blood pressure increases, and that the functions of the baroreceptors mainly for the transient change of blood pressure but not for the long term.

III. Chemoreceptors:

Baroreceptors are receptors for blood *pressure* (physics) but chemoreceptors are receptors for oxygen *saturation* (chemistry).

Chemoreceptors are NOT sensitive, so they take a longer time to react than the baroreceptors. Actually their effect will start when

oxygen saturation reduces to 60%-70% than the normal value. So they are mainly involved in hemorrhage (bleeding).

(OverDose 2019) :

- Chemoreceptors are presents at the same place with the baroreceptors .
- they are mainly sensitive to changing in blood chemicals (O2 ,CO2 ,H) .
- when the blood pressure decreased less than (80) and the less than (60%) oxygen saturation , these receptors will be stimulated . (when we have less BP … we expect to have less Blood flow , less Oxygen saturation .

Baroreceptors : changing in BP (acute change) .
Chemoreceptors : changing in Chemicals (need more time than Baro)
Bainbridge reflex : changing in Blood Volume . (needs more time)
CNS ischemic response : Generalized vasoconstriction . (needs more time)
Vasovagal Attack : Generalized vasodilatation .

IV. Atrial & pulmonary artery reflexes (Bainbridge reflex):

We also call them low pressure receptors because they are mainly involved when the blood pressure is high because of fluid overload that will cause an increase in blood flow.

When the venous return increases because of the volume overload, the atrial pressure will increase, so the right atrium will be dilated (stretched), that will also dilate (and stimulate) the SA node, so the heart rate will increase, also blood flow to the kidneys will increase, all of that will increase urine excretion to reduce the blood volume (excess fluid) thus reducing the blood pressure.

Also in patients who develop tachycardia or atrial fibrillation (AF) go to the bathroom frequently because the heart rate will increase, leading to a blood flow increase to the kidneys, thus the filtration increases and urine formation increases.

So simply Atrial & pulmonary artery reflexes (Bainbridge reflex) is:
Stretch the right atrium stretch SA node increase heart rate excrete the excess fluid bring blood volume to normal value.

Notice that it has nothing to do with frank starling law (frank starling law: the increased volume of blood stretches the ventricular wall, causing cardiac muscle to contract more forcefully) it is only applied for the left ventricle because the force of contraction of the atria is too small compared to ventricles.

Guyton says:

Atrial Reflex Control of Heart Rate (the Bainbridge Reflex). An increase in atrial pressure also causes an increase in heart rate, sometimes increasing the heart rate as much as 75 percent. A small part of this increase is caused by a direct effect of the increased atrial volume to stretch the sinus node; such direct stretch can increase the heart rate as much as 15 percent. An additional 40 to 60 percent increase in rate is caused by a nervous reflex called the *Bainbridge reflex.* The stretch receptors of the atria that elicit the Bainbridge reflex transmit their afferent signals through the vagus nerves to the medulla of the brain. Then efferent signals are transmitted back through vagal and sympathetic nerves to increase heart rate and strength of heart contraction. Thus, this reflex helps prevent damming of blood in the veins, atria, and pulmonary circulation.

V. CNS ischemic response:

This manly happens in hemorrhage or shock that causes a sever reduction of blood flow to the brain.

During hemorrhage if a patient loses a lot of blood, there will be tachycardia and the blood will be shifted from the venous side to the arterial to increase the blood volume in the artery thus increasing the blood pressure, because any change in blood volume in the

As we know from the previous lecture that CO_2 can cause vasodilatation directly and vasoconstriction indirectly.

arteries will significantly affect blood pressure, but in veins a significant change in blood volume will cause a minimal change in blood pressure.

This shift of blood happens due to severe sympathetic stimulation that will cause vasoconstriction (including veins) to shift the blood to the vital organs (brain, heart and lunges).

Later on if the hypotension continued and the blood pressure didn't increase there will be signals from the sympathetic center to cause a generalized vasoconstriction everywhere except the brain in the body to shift the blood to the brain because the brain tolerates only 4 minutes of hypoxia but after that the brain cells will die.

This mechanism is also called the last ditch either we save the patient or we lose him.

Also when someone stand up quickly he will feel dizzy, that is because of the hypotension that caused reduction in blood flow to the brain.

These are the mechanisms that control the sudden changes in blood pressure (acute control).

Few words from the doctor:

Usually most of the patients with hypertension are diagnosed accidently because people who suffer from hypertension don't have any complaints, that is why ***any doctor seeing any patient for any reason the doctor has to check 2 things: the pulse and the blood pressure whatever was your specialty.***

Hypertension is very easy to be diagnosed if we measure blood pressure as a routine procedure, and it is easy to treat it but we have to diagnose it firstly.

Don't you ever give a patient painkiller without knowing the cause of the pain, you have to reach a diagnosis first then you treat accordingly. It is better to wait than you treat wrongly.

(OverDose 2019) :

6- Abdominal and Skeletal muscles compression reflex :

- Abdominal :

#When the abdominal muscles (muscles of the abdominal wall) contract … this contraction will compress on the abdominal cavity (which has the main venous reservoir : Liver , spleen and the large abdominal veins) … this compression will shift the blood from these reservoir to the circulation … to increase blood volume (venous return) … to increase the output … to increase Blood flow and Blood pressure .

This reflex is stimulated through the skeletal nerves by a nerve signals that formed in the brain after an afferent signals from Baroreceptors or Chemoreceptors when the BP changed .

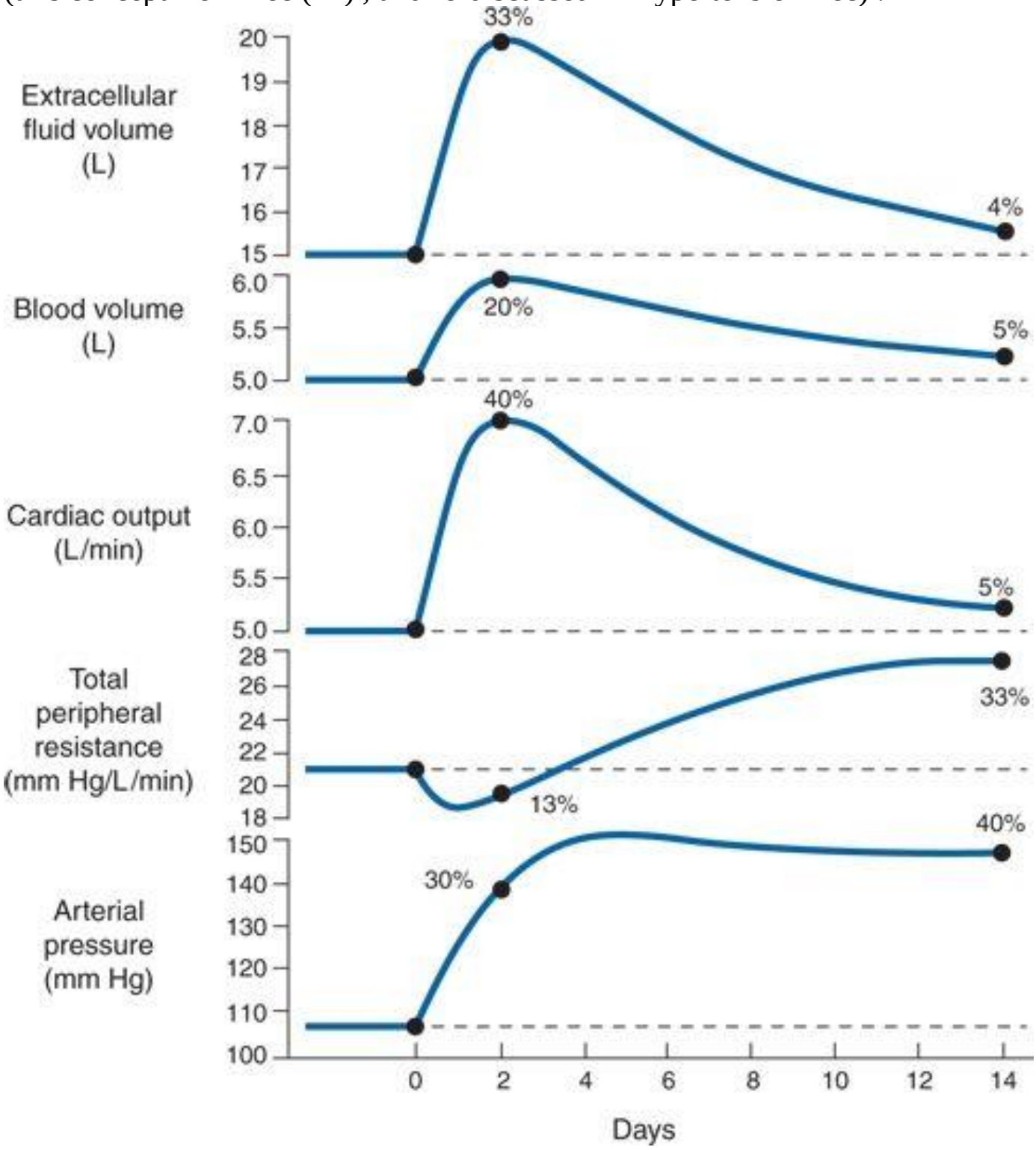
- Skeletal :

#When Skeletal muscles contract , the veins will be compressed ,,, and this will increase the circulatory filling pressure … and then the venous return ,, and then the end – diastolic volume … and then the Cardiac Output (By Frank-Starling Law) .

(Overdose 2019) :

 # Volume – Loading Hypertension :

(this concept from Lec (12) , and re-discussed in Hypertension Lec) .



- This is an experiment done to understand how the volume loading can lead to Hypertension :

- A week or so before the point labeled “0” days, the kidney mass had already been decreased to only 30 percent of normal. Then, at this point, the intake of salt and water was increased to about six times normal and kept at this high intake thereafter.
The acute effect was to increase extracellular fluid volume, blood volume, and cardiac output to 20 to 40 percent above normal.
Simultaneously, the arterial pressure began to rise but not nearly so much at first as did the fluid volumes and cardiac output. The reason for this slower rise in pressure can be discerned by studying the total peripheral resistance curve, which shows an initial decrease in total peripheral resistance. **This decrease was caused by the baroreceptor mechanism, which tried to prevent the rise in pressure. However, after 2 to 4 days, the baroreceptors adapted (reset) and were no longer able to prevent the rise in pressure.**
At this time, the arterial pressure had risen almost to its full height because of the increase in cardiac output, even though the total peripheral resistance was still almost at the normal level. After these early acute changes in the circulatory variables had occurred, more prolonged secondary changes occurred during the next few weeks. Especially important was a progressive increase in total peripheral resistance, while at the same time the cardiac output decreased almost all the way back to normal, mainly as a **result of the longterm blood flow autoregulation mechanism that is discussed**

That is, after the cardiac output had risen to a high level and had initiated the hypertension, the excess blood flow through the tissues then caused progressive constriction of the local arterioles, thus returning the local blood flows in all the body tissues and also the cardiac output almost all the way back to normal, while simultaneously causing a secondary increase in total peripheral resistance.

Note, too, that the extracellular fluid volume and blood volume **returned almost all the way back to normal along with the decrease in cardiac output**. This resulted from two factors: First, the increase in arteriolar resistance decreased the capillary pressure, which allowed the fluid in the tissue spaces to be absorbed back into the blood. Second, the elevated arterial pressure now caused the kidneys to excrete the excess volume of fluid that had initially accumulated in the body.

Last, let us take stock of the final state of the circulation several weeks after the initial onset of volume loading. We find the following effects: **1. Hypertension 2. Marked increase in total peripheral resistance 3. Almost complete return of the extracellular fluid volume, blood volume, and cardiac output back to normal**

Therefore, we can divide volume-loading hypertension into two separate sequential stages:

The first stage **results from increased fluid volume causing increased cardiac output. This increase in cardiac output mediates the hypertension**.

The second stage in volume-loading hypertension **is characterized by high blood pressure and high total peripheral resistance but return of the cardiac output so near to normal** that the usual measuring techniques frequently cannot detect an abnormally elevated cardiac output.

(Done By : Ahmad Dabbour)