Human Physiology
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Lecture – 17
Hemodynamics & Regulation - Part 1

Let us visit the slide once again. We are looking at what - a blood vessel. Where is that blood vessel travelling? It is in your viscera. Viscera means the organs in your abdomen which means again stomach, duodenum, small intestine, large intestine, all those blood vessels. What about those organs? In those organs there are blood vessels. We are talking about those blood vessels.

What about those blood vessels? They have sympathetic nerve supply. Are you with me? Where is it coming from? The neuron is located in the spinal cord. It will give rise to preganglionic fibre. It will talk to the postganglionic fibre, and there you can see the postganglionic fibre is now terminating on the smooth muscles of the blood vessels.

We are okay so far? And whenever it is excited, and brings action potential, then this postganglionic fibre will release what neurotransmitter on the smooth muscles of the blood vessels? Norepinephrine. What is it? Norepinephrine. Now what happens in reality is at any given moment, at any given moment, some of these signals are arriving over the sympathetic nerve at a certain frequency, certain frequency. As a result of that all the muscles of the blood vessels are actually in a slightly contracted state. What state? There is never a situation in which no information is coming from the sympathetic nervous system and as a result of that all the muscles may be fully relaxed.

No, they are always slightly contracted. Now - nature has a purpose in this. When they are slightly contracted, how are you controlling it by sending the information? How - number of action potentials per unit time? Are you so far? And some are always coming as a result of that there is some contraction of the muscles of that tube there. Now sympathetic nervous system can, it has two options. If necessary it can increase the action potentials and reduce the diameter.

Are you with me? On the other hand if you want to supply more blood you can reduce the action potentials and dilate the diameter. Are you with me so far or not? What am I talking about? I am talking about the regulation of the diameter of the tube. What is this tube? It is a blood vessel. Where is that blood vessel? It is in the wall of the alimentary canal. Okay, so far.

And you are trying to control the diameter of the blood vessel. Why do you want to control the diameter of the blood vessel? Well, if there is food in that part of the alimentary canal and if you want to increase the activity, enzymatic activity, secretory activity, peristaltic activity, then you need to dilate the tube so that you increase the blood supply. But it is now 4 hours, 6 hours, you have had no food, your intestine is actually doing no great, then actually it may be a good idea to constrict it so that you can send the blood somewhere else where it is required. Are you with me so far? Okay, great. So you are continuously monitoring, okay.

So what do we have here? If you reduce the frequency with which action potentials are coming over the sympathetic fibre, if you reduce then what happens to the diameter of the tube? What happens? It dilates and it will allow more blood to flow. Now let us go back to the yesterday's example when you are running for your life. And in that particular case, the sympathetic nervous is stimulated, different components of the sympathetic nervous system are stimulated and I will briefly tell you how the nervous system in different components has profoundly different effects. But they all serve the same purpose, the same end result and that is a very interesting part and let us focus on that. When the sympathetic nervous system is stimulated, essentially two things happen.

Number one, the information coming over these sympathetic fibres and sympathetic innervations which goes to different parts of the body, they go up. More action potential, more, more. So step number one. Step number two, what sympathetic nervous system also does is, now do not forget this point, it also stimulates the adrenal medulla. What did I say? It also stimulates the adrenal medulla.

Very good. What does it stimulate? Adrenal medulla. And adrenal medulla is a source of two hormones. I am sure you are aware of that. Can somebody please tell me the two names? Adrenaline and noradrenaline. Will you say that loudly? Adrenaline and noradrenaline.

These are two hormones. And these two hormones are secreted in the blood. What is the neurotransmitter being released by these neurons? Norepinephrine. Same as noradrenaline, same molecule. Is it releasing epinephrine? No.

Say that no. What is it? No. Is it releasing? No. But the cells are getting epinephrine via two sources. Number one, postganglionic supply of the sympathetic fibre source number one. And source number two, norepinephrine is also coming through the blood released by the medulla.

Hello. What am I talking about? Okay. Okay. Let us go to heart. In the heart, let us go to muscle. Heart muscle, muscle of a ventricle.

In that you have receptors. Receptors or what? Adrenergic receptors. Good, good. Now you are being chased by a drug, your sympathetic nervous system is stimulated. So the sympathetic nervous system that starts at the level of T1, T2, T3, T4, okay or not? Okay or not? Are you okay there? And then it is preganglionic, postganglionic.

What neurotransmitter is it releasing there? Say that again. Norepinephrine. At the same time sympathetic nervous system has also supplied the? Also supplied the? Adrenal medulla. Adrenal medulla. Also supplied what? Adrenal.

What is adrenal medulla? It is an endocrine gland. Say that again. Endocrine gland. Endocrine gland. What hormones it is releasing now? Adrenaline.

Adrenaline and noradrenaline. Both these hormones are going where? In the bloodstream and as the blood flows everywhere that adrenaline is also now going to the heart. So that heart muscle in the ventricle which was getting norepinephrine through a nerve end is also getting adrenaline through the blood. Are you getting the entire story? So the adrenaline, so the when you stimulate the sympathetic nervous system two things happen. Either norepinephrine is delivered by way of a fibre to its target organ or through the blood. All over - whether you are connected by a nerve fibre or whether you are not connected by the fibre - you are always connected by blood and through the blood you can get not only epinephrine or not only adrenaline but not only noradrenaline but also you get adrenaline.

Are you okay so far? Good. Now, so remember these two points. Now let us go back to our story of being chased by a dog. As a result of that this sympathetic nervous system is stimulated and blood vessels narrow. So what will happen to the blood vessels of your alimentary canal? Look at the diagram and tell me the blood flow will go up or go down? Go down, go down, go down. At the same time this action is via what kind of adrenergic receptors? Alpha 1.

Say that again. Alpha 1. Alpha 1, adrenergic receptors are those receptors on which adrenaline can also act noradrenaline can also act. Action is slightly different I will not talk about it now. Good. Now let us come to the point. So this action that you are getting, okay, this action, few action potentials, less action potentials you get so much diameter, more action potential you get reduced diameter.

Okay, good. This action is possible because on the plasma membrane of those smooth muscles in those blood vessels they are of alpha 1 adrenergic type. What did I say?

Alpha 1 adrenergic type. Means what? Means what? Well we have receptors, they all look the same, they all respond to norepinephrine but some of them respond to drug A, some of them respond to drug B, therefore I will call A type and I will call B type. In this particular case what do I call them as? Alpha 1. Actually if you go in detail in pharmacology alpha 1, alpha 2, beta 2, there are many, many, many.

Let us not go into that, just alpha 1. What is it? Alpha 1. So where do you get alpha 1? It is here. Now, so now I have told you where you will find, so I will ask, okay fill in the blank. Alpha 1 adrenergic receptor was simply found where? Smooth muscles.

Smooth muscles. Everybody has to shout. Smooth muscles. Smooth muscles. Where? Smooth muscles where? Blood vessel. Where blood vessel? alimentary canal.

Not everywhere, not everywhere, alimentary canal. Remember this. Now I will take you to the blood vessel in the skeletal muscle. Are you with me? Where am I taking you now? Is it the same blood vessel? No, it is in the skeletal muscle. The blood vessel in the skeletal is equipped with beta 2 kind of adrenergic receptor.

What kind of? Beta 2. Beta 2 and beta 2 kind of adrenergic receptors gives exactly opposite response. Means what? It dilates. It dilates. So just imagine as a result of the sympathetic nervous system stimulation, same, the norepinephrine is going there directly. Adrenaline and norepinephrine are going through the blood.

Whereas those smooth muscles in the alimentary canal are, those in the muscles are. Are you getting the drama very clear? Means what will happen to the overall picture? The blood will be transferred from the alimentary canal into the muscle where is required. Are you getting the argument? So the beauty here is using the same epinephrine, adrenaline and non-adrenaline as the molecules, are the responses same? Are the responses same? So one thing that you have to remember is never do the mistake of saying that this is excitatory or this is inhibitory.

No. A signaling molecule, noradrenaline as a signaling molecule will bring about the constriction of this muscle of these smooth muscles of the blood vessel in the alimentary canal. Whereas the same, same neurotransmitter or hormone in the case of skeletal muscle will have exactly opposite action - means where it will bring out what? Dilatation. Are you with me? So never do the mistake of saying that norepinephrine is inhibitory.

No. You have to ask a question. Neurotransmitter good, neurohormone good. What receptor is it acting on? On what receptor? And where is that receptor located? And then what is the effect? Then only the story is complete and so what is the effect of any neurotransmitter or a neurohormone on a target tissue will depend on what receptor and where? Is the message very clearly taken? Now. So alpha 1 receptor where? Tell me where. Smooth muscle of the heart.

Very good, very good. Beta 2 receptor where? Smooth muscles of the blood vessels. Now in your windpipe, here, here, here trachea, it is also supplied with smooth muscles. Those smooth muscles are also supplied with beta 2 adrenergic receptors which are similar to those in the blood vessels of the skeletal muscle. And when they are excited, they dilate, they dilate. Are you with me? And you already know that when epinephrine, adrenaline and noradrenaline, it goes to the heart, it acts via on the heart muscle, not now blood vessel, heart muscle, heart muscle, cardiac muscle, plasma membrane, beta 1 adrenergic receptor.

Now fill in the blank, beta 1 adrenergic receptor can be inhibited by? Can be inhibited by? Ok, ok. Inhibited by drug, drug, drug. Drug propranolol, you remember propranolol. Hello, hello, hello, hello, hello, propranolol.

What is propranolol? Beta blocker. Beta blocker, it is a beta blocker. What is it? Beta blocker.

So now let us forget about propranolol. Ok. So now again go. So, yeah. Which one? Afterwards, you are breaking my story. Ok, I will answer your question.

There is no time for this. Ok. So again you are being chased by a dog. So, as a result of the stimulation of the adrenergic system, whether it is sympathetic postganglionic or whether via blood, ok, same system is doing lot of wonderful things. Number one, it stimulates the heart via beta 1 adrenergic receptors, heart muscles.

You need to run, ok. You need, your heart needs to pump. Your muscles need to get, ok. Number one. Number two, the same system relaxes your tracheal muscles so that it expands and so that you can breathe more easily because your oxygen requirement has also gone up. The same system also contracts the muscles of the smooth muscles of the alimentary canal because the alimentary canal does not need blood now.

Who gets the priority for the blood? Skeletal muscles. So you contract this here, send the message. So there are n number of changes which all put together. Something is going up, something is going down, all those things ultimately serve the same purpose. What was the purpose? To make you run, save your life. Are you getting the argument? So look at the beauty of the sympathetic nervous system.

It helps you in emergency. Same two agents. Same two agents are same, same, same. But the responses in different organs are different, ok and thereby it helps you to, ok. With this, I think I have given you the, yeah, yeah.

Yeah. Ok. No, no. See this is directly going as a neurotransmitter. So there is a smooth muscle and there is a supply and it will release norepinephrine. Norepinephrine will on the plasma membrane of the smooth muscle there will be alpha receptor. It will act and it will bring about the reaction, action whatever, ok.

That is one. Now at the same time there is a capillary going there. In that capillary there is adrenaline coming. That adrenaline will diffuse out. It will go into the extracellular fluid. While the extracellular fluid will now come in contact with the plasma membrane.

In the plasma membrane alpha 1 receptor is sitting there. It will act on the alpha 1 receptor and it will trigger the intracellular reactions. Ok, so it has to act on the out side. Of course, of course, of course, of course. These hormones, these hormones they never go inside.

They never go inside, ok. The almost all the receptors for adrenaline and noradrenaline, ok or even acetylcholine they are all on the surface. They are on the surface of the plasma membrane, ok. The 7 transmembrane and it has to go from outside. It can the binding site is on the outside, ok.

Inside it will be cyclic MP or IP3 or whatever. I will just go fast today. You can read this, read this, read this, ok. This is just to we have already done this once, but it is worth touching it once again, ok. What is the histological difference between a major vein and a major artery? Major vein, major artery has lot of it has to cope up with lot of pressure. Therefore, the wall is thick and the smooth muscles are strong and they are fortified as compared to that in the vein, ok.

Just to make the point the author does a very simple experiment. Let us take a vein and an artery. How long? I will take 10 centimeter long artery and 10 centimeter long vein. Are you with me? I will fill it with water, but do not give any pressure. Whatever volume it accommodates that volume that whatever it is I will call that volume as what? 1. Are you ok so far? Now, I will apply pressure and I will apply pressure and my pressure suppose it goes to say 40 mm Hg and now I check the I check the volume.

I check the volume I find that the volume of the artery has gone from 1 whatever it was it has gone to about 1.75. Am I ok there? Yes or no? The volume of the artery has gone, but if I do the repeat the experiment using a vein then where does the volume go? It almost goes to what? 4. So, who has more compliance? Vein. Vein has a far more compliance because the simple logic the walls are thin and that is why this also correlates with the point that at any given moment the venous system has how much blood about?

60, 70 percent of the blood is there whereas, in the arterial system little about 14 percent of the blood is so much less under high pressure. You remember we did a very tiny very interesting experiment where we had a tiny transducer and imagine no imaginary transducer I have and we put it in the left ventricle you remember? Hello? We put it in the left ventricle and magically it is giving me on my oscilloscope. It is giving me the pressure and as long as it is in the left ventricle I find it goes almost from 0 to 120 in the ventricle 0 120 mm Hg with every beat? It has to be almost 0 because the ventricles have to expand - the blood has to come from the auricles the blood in the auricles already has a very low pressure almost 0 maybe 1 or 2 mg I do not care very low. Then what I will do I will allow my transducer to flow through the blood just let it flow with the blood. So now the ventricles have gone in systole and as a result that transducer has gone along with the blood and from the left ventricle it has entered into the aorta.

It has entered where? Aorta. Aorta and as soon as it has entered into the aorta and the semilunar valve are closed then my transducer tells me 120, 80, 120, 80, 120, 80 because in the aorta it does not go to 0 are you with me? Why because the semilunar valves would not allow me to go below 80. So now here I am in the aorta here now I am in the aorta and I can get the oscillations of with every beat I go how high do I go?NKS read so far July 120 and with every with every and then when it falls when the heart goes to the diastole it goes how much? I am getting the pulse where is the blood in the aorta can you get the pulse there? Okay and the pulse is also aided because there is compliance of the aorta when it is 180 the aorta expands okay and when the heart goes into diastole it again contracts so that it keeps on pushing the blood we have done this point already. So now I am there now I go into the so if this is the if this is the aorta then I go into one of the branches I go into one of the branches I go into the into the large artery do I see do I still get the pulsation there? Yes or no? Yes. Yeah and then I go further I go into what I go into the small arteries do I get the pulsation but the pulsation has gone down now are you with me so far? Yeah and then from now I am I go into the arteriole and as I go into the arteriole the pressure is about how much about 80 is there okay? And by the time I go to the end of the arteriole the pressure the mean pressure the pressure has fallen to how much? 30.

30 mmHg how much it is? 30 mmHg. 30 mmHg now it is this is I am ready to the blood is now my transducer is ready to enter from the arteriole into the capillary network as I am ready to enter into as the transducer is ready to enter into this thing what pressure

is going to experience? See there say that tell me how much it is? Maybe it is about 30 okay okay okay okay okay now it is about ta ta ta ta about 30 how much it is? 30. 30 30 so as you enter in the capillary what pressure is the blood going to exert on the wall of the capillary? 30. 30 okay by the time blood passes through the capillary whose length is how much? 1 mm. 1 mm whose length is how much? Maximum 1 mm maybe half maximum 1 mm by the time it has crossed the distance of 1 mm and it is on the other side of the capillary okay the pressure has fallen to how much? It is about it is about 8 about it is about 8 it is about how much? 5, 6 whatever it is okay it is very low so just see within the tiny tiny distance there is a there is a tremendous ball okay and then after all and then you are here and then the blood has gone from the capillary into the vein and then the larger vein and larger vein and maybe inferior vena cava and from inferior vena cava what is the blood pressure in this? Come on just see just see we are talking about what 2, 3, 4 mm H. Now the blood from there vena cava it will enter it will go back to the heart it will go to the right oracle done right oracle is still extremely low from right oracle it will go into the right ventricle am I okay there? In the now the right ventricle is now what? Systole diastole, systole diastole, systole diastole and now that is oscillating in the range of we have seen this yesterday 25, 8, 25, 8, 25, 8 never make that mistake 25, 8 okay they are not same.

So although that is the beauty of the heart 2 compartments 2 compartments handling same volume at the same time but operating in different pressures. It is beautiful there is nothing this apart from this little science and huge beauty same heart same heart same volume okay the distance to be covered is very different lungs are so short and so near rest of the body so large so much okay same volume different pressures great and different and the I just make a statement I want you to hold on to the statement till I go to the lungs it is very important that the pressure in the lungs is very low very very important I just make a statement and leave it leave it to there if the pressure blood pressure in the lung rises you will drown and die in the fluids in your lung it is a radical statement I am making you will what? Drown and die because of the so much so much so much fluid will come out if the pressure is high so much fluid will come out that there will be a layer of water between your lung alveoli and the air and the air just would not be able to get into the blood okay therefore it is absolutely necessary that the blood pressure is extremely low in the case of what? In the case of the lungs we will talk about it when we talk about the lungs okay okay so and then so you oscillate between 825 and then you go to the and then you get back you get back where you get back to the left oracle and then the left ventricle okay I am sure you have seen this we are talking of the compliance of the aorta I am sure we are we have we are seeing this figure for the third time here again we are seeing the look at the look at the compliance of the aorta. Thank you.