Human Physiology
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Lecture – 22
Hemodynamics & Regulation - Part 6

So, we have seen this the sympathetic nervous system, where is it? The sympathetic nervous system from the from the ok. Does anybody remember from what level of the spinal cord or vertebral column, do you get the preganglionic fibres which are coming out and going to the heart? T T 1, T 2, T 3 and T 4 that is it. So, from here from here thoracic 1, 2, 3, 4 ok. The spinal nerves which emerge from that area go to the go to the preganglionic, and then the post ganglionic fibres will release norepinephrine on the heart and we have done that ok. So, this is a this is a block diagram that tells you how the changes will happen at every stage and so, you can you can.

So, just see baroreceptor reflex - if the pressure falls, let us follow this through. Baroreceptors - pressure falls, stretch on carotid sinus goes downward - means what? Reduce then what? Firing rate for carotid sinus will go down as we have seen in that slide. Then as a result of that parasympathetic activity will also of the heart will go down ok. Are you with me? This will go down therefore, the heart rate will go up. ok.

So, you are sitting in the middle of medulla oblongata and you get the information that the pressure is not good enough. So, the first thing that you do is shut off, shut off the parasympathetic nervous system. So, is the heart getting enough acylcholine now? No, it is not getting enough acylcholine ok. So, it is not inhibited. In this particular case acylcholine is acting by what receptors? Acylcholine.

Acylcholine, muscarinic, muscarinic, muscarinic, M 2 what is it? Muscarinic. You know something what we have seen so far are rapid changes, rapid may be immediate in seconds or in minutes or in hours ok we have seen. There are some of the changes which happen over a very long period of time ok and the classic example or the classic experiments that was done. You know what was the very elegant experiment. You take the fertilized chick eggs, are you with me? Fertilized. So, is the development happening there? Yeah, development is happening there ok.

Then what you do? You take two incubators, are you with me so far? In this incubator you have normal air, in this incubator you have air which has less oxygen. So, if this is

normal and if I presume this is 20 percent oxygen am I ok there? Hello? Roughly give and take something 20 percent is here. I will in this chamber incubation, incubation chamber I will have 10 percent oxygen and then I will put the eggs in both ok and then I will let it develop for say 10, 15 or do not go to the end, you see just for 10, first 10 days, and then take out both the eggs ok and then I open both the eggs and put them under microscope or even without putting them in the microscope I find that in this egg which was in incubated in what? 10 percent oxygen. I find that there is far more the number of blood vessels is very higher as compared to this. What has happened? Can somebody guess? Just the number of the number of arteries, veins, capillaries everything is much more means the blood vascular system is sensitive to the amount of oxygen and when the amount of oxygen is less, our physiological systems compensate by giving what? By giving what? Increased your own RBC count maybe 5 million ok per cubic mm or whatever maybe huge, huge.

If you go and stay at higher altitude like in some place in Himalaya or Laddakh over a period of 15 days you will find that your RBC count has gone up. Why is it going up? Because why has it gone up? Because when you go there your physiological systems realize that there is less oxygen so you try to compensate. It takes time ok it takes time but you are you are able to and the last is actually amazing. We never think of these problems you know but they are there the problems are there. The problem is a there is a case of birth of a baby. Are you with me? And the baby is not doing too well so you put the baby in incubator ok and you want to make sure that the baby is well protected, baby is not able to respire properly on its own therefore you increase the supply of oxygen.

So where is the baby actually I will say that the baby is in oxygen tent. So the baby is getting plenty of oxygen no problem. So whatever its development is happening is happening. Now after you cannot keep the baby there forever. After 15 days or 1 month you decide to take out the baby. The moment you take out the baby, baby experiences that the oxygen is far less and then there is a profound rebound in the circulatory system and there is so much of blood vessels that some of the blood vessels, the number of blood vessels, increase. Elsewhere it does not matter but they may increase in the retina and if they increase there then it may it may, those blood vessels may obstruct the vision.

Hello are you getting the argument? Are you getting the argument? Ok so you can you can talk about the changes over a period of longer period of time. Very interesting point read about it. Yes please. The changes that are caused in this case does it reverse after like hatching in a normal environment? It does, it goes down it does go down. Yeah it is I mean those changes are happening because there is a certain trigger.

Ok when you remove the trigger eventually the things will come back to normal. But I

do not know how far I mean, how far if you have gone it will come back that I do not really know. But you have to work, but literature is there on that issue. Ok now I will talk about a very interesting issue and I am going to we always talk about lymph you know lymph lymph lymph ok. Let us talk about lymph it is one of those topics which you know which we know is there but we generally do not talk about it. Am I right there? Always in a book you know there is a topic I know it is there I know somebody says it is important.

I also did it. But then when we do that ok in our primary instinctive behaviour towards the studies ok we miss fun ok. So, therefore, I am going to talk about this lymphatic system. You know what happens if I ask you tell me the name of the organ where ultrafiltration is happening you will instantly tell me kidney ok. Am I ok there? Can you tell me the name of the organ where ultrafiltration takes place? Kidney.

I am going to repeat my question can you tell me the name of the organ where ultrafiltration takes place? Kidney. I am not getting the chorus you know you see that I will tell you why that chorus gives me a kick and you are depriving me you are depriving me of that. So, tell me the name of the organ ok. You know something at the level of every capillary every capillary small amount of ultrafiltration is happening. Very interesting, every capillary, small amount of ultrafiltration happening and the fluid flows out and why do the fluids flow out because there are capillaries and there are capillary endothelial cells and some of the endothelial cells have gaps ok and through the gaps the fluid can go through the fluid the fluid ok. Here is the capillary ok and in the capillary there is an endothelial cell there is another endothelial cell and whereas, the oxygen and oxygen can safely go out and whatever and carbon dioxide can get in and nitric oxide can get in there are small molecules like amino acids and other molecules etcetera they can just go through this gap ok and there are some molecules which have carrier in the endothelium.

So, there is lot of trafficking can happen etcetera. But the point is that the small molecules can go in and out, but large protein molecules cannot go. We have seen that already when we studied capillary and the large proteins. So, large protein molecules are confined here ok, but is the system so perfect that no large molecule will go. No system is perfect ok. So, there is some loss of some loss of large molecules also. So, you can have ultrafiltration here, why ultrafiltration because just as the blood is about to enter into the capillary the blood pressure is about 30 mm Hg and given the fact that capillary endothelial cells are extremely thin and delicate and the space is it is the fluid is going to come out ok and along with that fluid some large amount of proteins are going to come out. Now, what will happen if you allow the proteins to stay there. Bad idea. You cannot allow the proteins to stay there therefore, and all the substances which have come out as a

result of ultrafiltration.

The nature has provided us with an amazing system wherein those substance, there is another system of tubes, another system of capillaries and blood vessels which return those substances back to the circulatory system and that I can show you in this image. You can see how the system, how the substances can flow out ok. So, here we have the capillary where is this capillary network it can be anywhere muscle, pancreas, anywhere and here is the oxygenated blood, comes here, goes into capillaries and there is a system - there is certain fluid that is flowing out of the capillaries under the influence of higher pressure and that it gets into tiny tubes, and then flows through the tubes ok. and it will finally it is poured into the vena cava, superior inferior vena cava, and then finally it returned to blood, ok. In this you will never get an RBC ok because RBCs are very large but you get plenty of WBCs, you will get large protein molecules and you get lot of filtrate. Now, remember this I will take you back to this interesting point. Focus on this. We are looking at, look at the bottom, can you see the capillary there, ok.

What do you think is the distance from this end to that end of the capillary? How much? How much? 1 millimeter. 1 millimeter ok. Alright, and, if I measure the pressure here ok, it is going to be how much? 30. 30 and how much is going to the pressure here or that is actually represented by this green line. So, these two points are represented by - can you see the green line there and can you see go to that y axis. So, what is the pressure of the blood as the blood is entering into the capillary - read there? 30 mm Hg.

Little more than 30, 32, 33 - whatever that author is showing and by the time it goes to the other end, where are we, we are here - about say 12, 13, 14 are you ok so far? Now, as a result of the fall in the blood pressure the material is getting filtered out of the capillary due to ultrafiltration and how much of blood is being filtered out can be judged by way of the length of the arrow. Now, why - can you guess why this arrow is slightly longer than the second arrow? Higher pressure. Higher pressure, higher pressure, lower pressure and in the third in the pressure is almost less. Now, just as, get the point, follow this, just as the pressure hydrostatic pressure generated by the heart is going from 32 or whatever is going down and as a result of ultrafiltration some of the protein molecules are going well few of them, but they are also going ok. Now, we look let us look at the blood.

The blood as it is available at this point has a certain osmolality are you with me, has a certain what? Osmolality. Osmolality has a certain osmolality as the blood flows, fraction of a millimeter, by fraction of a millimeter, by fraction of a millimeter, the most watery part will flow out easily? Large protein few, but not many. What is the dominant factor that is flowing out? Watery part. Large protein 99 percent of the large proteins are

still confined to that. So, by the time you reach here or here, here or here what is the physical composition of the blood? Less water and more large proteins which means more osmolality are you with me? Now, so as I go from here to here the osmolality is increasing and the blood pressure is decreasing are you with me? So, I am getting exactly opposite picture from the first half of the capillary versus the second half of the capillary. More have more blood pressure, more blood pressure, less osmotic pressure, more osmotic pressure, less blood pressure. As a result of that a large amount of blood a large amount of fluids which are going out here are getting in there. Hello, just imagine how much of drama is happening within 1 mm of the length and given the fact that RBC takes less than a second to go, but within that time this continuously the fluid is coming out and continuously the fluid is going back.

This was described this we call as what? Starling hypothesis what do we call it as? Starling hypothesis. Now, this Starling name is coming for the second time. When did it come for the first time? Say that loudly. Frank Starling hypothesis or Frank Frank starling mechanism of heart or law of heart. Have you forgotten that mechanism? Lost, gone for good ever, goodbye.

Remember that. Same Starling, Frank Starling a British scientist and the time is about 110 years from now, 1910 or something like that. He discussed the phenomena, he described the phenomena that across a capillary the things come out, come out, come out, they are going, going, going. And it has been found that over a period of 24 hours within a human body the total amount of filtrate that comes out of all capillaries is about 20 liters is a huge quantity. Out of that 20 liters about 17, 18 liters goes back, comes out in the earlier part of the capillary, goes back in the later part of the capillary out of 20 liters, 18 liters has gone back, how much has remained? 2 liters, 2 liters has remained. If you do not return the 2 liters to the blood vascular system you will have swelling in the tissue, edema in the tissue.

So as to make sure that you return that 2 liters over a period of 24 hours, back to the circulatory system. You have that lymphatic system which we have, which I have told you. Are you okay so far? Hello, you have got the philosophy of the lymphatic system, okay, lymph is generated at every capillary at every moment, certain microliters each generated, okay. And lot of it goes, 80 percent goes back, 80, 90 percent goes back, but what does not go back, okay, for that we have the lymphatic system and that lymphatic system is not just that eventually lymphatic system has lymphatic nodes and those lymphatic nodes play a very important role in what? Immune system. Immune system, okay, so that is a part of the, that is a part of the immune system. This is approximate number you know what we have seen in the previous slide, the author is trying to give us some numbers, what are the numbers? The blood pressure in the earlier part of the

capillary is about how much? 32.

32, is the effective pressure. 32 not really because outside also there is fluid, in that outside fluid also there are salts and there is also some protein that is also generating certain osmotic pressure and that pressure is about how much, about 22. So what is this minus this, will be how much? 10. So the fluid is going out at 10, it will actually be 10. It is absolutely – will be reducing, you know from capillary as you go to the centre, it will be reducing and as you go from here, okay the blood pressure has gone down, okay this is more or less remains 22 or whatever and then as a result of that the net pressure inside is minus 7 so the fluid will go back, 100 percent no, no, 80 to 90 percent whatever 10, 20 percent still remains it has to go where? It has to go into the into the lymphatic system. And I wanted to finish but it seems it is difficult for me but in the next lecture I will try to finish the topic on the lymphatic system