Human Physiology
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Lecture – 37
Respiration - Part 1

Lungs strike us as very special organs because here we bring about the interaction between air on one hand and the blood on the other. And interface is at the alveoli where the two things are going to interact, air and blood. You can ask a question how much of air and how much of blood. When I talk of air I talk of ventilation, this is a process of ventilation - we take in air so what you are really doing when you are breathing - you are really ventilating your lungs. And when you are ventilating certain amount of blood is flowing through the lungs. Is there a correlation between the two and what is the healthy correlation is a question that we are asking.

Are you with me? How much of blood versus how much of air per unit time - one minute. And it has been found that over a period of one minute in a healthy person about how much of air that you are taking in and giving out - 4.2 litres a minute. Given the fact that you are respiring, you are 70 kg, you are in rest and you are breathing normally and in that period the number of - you may be 8 or 10 or 12 breaths, but we are roughly on an average would be how many how much of air is there that is going in and out.

How much air have you taken? 4.2 liters. During that period how much of blood has drained through the lungs and that comes to about - 5.5 litres. Means what? The blood that is coming from the heart and going back to the heart over a period of one minute is 5.5 liters.

And so I am just going to divide one by the other and I get a ratio of about 0.8. Why is the ratio important? The ratio is important because - depending on the physiological condition - the ratio can change. About that I do not really care much, but what I really care about is - it can really vary during diseased conditions. And then it can give me a good parameter about the functioning of the lungs.

If the ratio is changing and in what direction it is changing. So what are we going to do now? So let us take some examples and find out. Now as long as you are sleeping down, let us presume that the effect of gravity is there but let us presume that it is not there. Its reality is there but it is certainly glaring when you are standing. The effect of gravity is there.

So whether you like it or not the gravity is pulling your blood down. So I will ask you a simple question. Is the amount of flow of blood, I divide the lungs into three parts, actually it is continuous one but I will still divide into three parts for the sake of argument. And the argument - I am dividing the heart into three levels. Are you with me? Top level, middle level and the lower level.

Is the blood flow same through at all the levels? No, it is not same. Why? Because when you are standing the blood would like to, if given a choice, it will like to go along the gravity which means it will flow through the lower part and it will be minimum through the higher part. So is the ventilation-perfusion ratio uniform in the lungs? It is not going to be uniform. It is going to be different when you are standing, it is going to be different when you are sleeping, that is point number one. Secondly, then there are a range of conditions which will also influence the ventilation-perfusion ratio.

In this diagram, well we have millions of alveoli but the author has focused on four alveoli, just example, four alveoli. And you can see there 1, 2, 3, 4, can you see the alveoli there? And in the alveoli can you see there are the bronchi and the bronchi are branching and all the four of them are being ventilated by a single bronchus each. Now the first one, this one at the top here is very normal. What is there? Can you see from there the deoxygenated blood is coming? Hello? So the deoxygenated blood is coming and then it gets oxygenated and goes all the way. So deoxygenated gets oxygenated, goes here and air also comes in and goes out and the blood has an opportunity to collect whatever oxygen it can.

But what is the difference in this? Is this alveolus also getting equal amount of oxygen? Yes or no? What does it look like when you look at the image? The second one, the second one no, there is a problem. Maybe there is some fluid accumulation, blood accumulation, I do not know what. But as a result of that the air cannot really enter into the alveolus. Not that all the 300 million alveoli, are really functional? It is not.

So what is it doing? It is impacting the ventilation-perfusion ratio, adversely. The blood is flowing but it is not getting oxygen. The second factor can be here for example, now let us compare this with this. What is the difference between these two alveoli? You will find that the capillary that goes here, whereas this is a healthy capillary, it carries the blood, whereas this capillary is almost shrunken, it is not taking the blood, something wrong in the capillary. But then is that alveolus getting air? Yes, it does.

Does it get blood? No. As a result of this is oxygenation happening? No. Again adversely influencing the ventilation-perfusion ratio. Let us take a third example, wherein the air comes and goes, no problem, where the blood flows no problem, but is the blood getting oxygenated? No, no. Why perhaps because of some reason, maybe the blood pressure somewhere there has increased, as a result there is accumulation of fluid, as a result of that fluid - which is lining the alveolus - serving as a barrier. And when a barrier obstructs the passage - two way passage of oxygen and carbon dioxide - the transfer of oxygen into the blood is not happening.

So these are the different scenarios in which the ventilation-perfusion ratio can be adversely influenced. So look, yes please. The ventilation rate depends on everything put together. Because we have sensors for oxygen and those sensors for oxygen are somewhere in the carotid, I will talk about it and it will take the blood as a whole. Although oxygen sensors are there in different part of the lungs, but as of today, we have not been able to discern their functions. So your argument could be partly right, I am not very sure.

The final 0.8 number, it is the average of the three sections you are talking about. Which one? Okay. It is average of everything, average of sleeping, standing, etc. Okay, now we will take a look at this nice diagram. You know you have the alveoli and then you have the capillaries and you can see the blue ones which are getting oxygenated and the blood is going out. I will ask you a very simple question - you know we have balloons on birthday etc.

we blow into the balloons okay and we believe that it is an excess load for the lungs. Whatever. You know something when you actually put a balloon to your mouth and try to blow into it, there is so much pressure being applied onto the balloon - that pressure is coming from your lungs. The pressure also goes to the alveoli and the pressure on the alveolar capillary becomes so much that actually the blood stop to flow in the capillaries. Hello, are you with me? As long as you are blowing into balloon okay. So means what each balloon is now stretched okay you are generating pressure, okay. It is stretched and the alveolar pressure is so much that it presses on the capillaries and as a result of that the blood flow in the capillaries is almost stopped as long as you are blowing with a high degree of pressure, okay.

Therefore you have to take a break and then the and as soon as you take a break the blood flow in the alveoli in the capillaries of the alveoli will restart. What am I doing? What am I doing right now? I am trying to impress on you the importance of the alveolar pressure on the flow of blood, okay. Now there is such a delicate balance - extremely delicate balance because if you want to make sure that the blood flows in any case. I am going to increase the pressure if I am increase the pressure then there will be more leakage of the fluid and accumulation of the fluid in the alveoli which I do not want. That may serve as a barrier, okay. If I want to reduce I know that in the capillaries the pressure is about 7, 8 mm Hg, okay. I do not want the blood to leak out of the capillaries so what I am going to do is I am going to reduce the pressure. If I reduce the pressure, the problem is the alveolar pressure will kill me and no blood will flow through the capillaries are you getting my language? What am I talking about? I am talking about - you have to make sure that the blood keeps on flowing through the capillaries of the lungs. There is a very delicate exercise - I cannot increase the pressure under which the blood is flowing through the capillaries because there is another problem - you cannot reduce it okay because if I reduce it then the alveolar pressure will dominate and the flow will stop altogether - something that happens when I blow into the balloon. Are we done? Okay good. So let us talk about the three pressures okay. Let us see blood flow what through the lungs. Okay. What am I doing? I am going to divide the lung into three parts. What part is this and what part is this and what part is this and then under the standing - just standing at rest the red what is how much at the top how much is the blood supply? Whatever how much is the blood supply with reference to this in this lower so in the lower most the blood supply. This is the scenario during what condition - at rest now you are doing exercise. you see when you are doing exercise lots of things happen. Number one - the heart rate will go up the force with which heart is contracting - the cardiac output will go up 4, 5, 6, 7 times - huge amount. Means that blood is also going from the heart into the lungs so all that amount of blood which is coming from the heart as a result of exercise all that is flowing through the lungs, okay. How does the lung suddenly manage with the huge amount of blood. Huge amount 4, 5 times is huge, okay. Means under normal conditions, if the cardiac output was about 5 5 liters, moderate to heavy exercise it may go to 18 to 20 liters. How does the lung cope up with suddenly increase in the volume of the blood that is being processed through its blood system. The number one is the - under resting conditions lot of a large number of capillaries may be inactive hello you get the point inactive capillaries. As you start doing exercise several capillaries get activated means now they are ready for perfusion and the blood will flow through them. At this moment I can ask you to reflect back and I will ask you a simple question. Can somebody tell me why is it a good idea to do exercise - to regularly activate inactive capillaries. Got the answer. It is in your interest to make sure that that all the capillaries become activated. You have to just make them functional okay. To make all of them functional okay - I am not talking of other things but just looking at the health of your lungs okay, it certainly makes sense to do exercise so that all the capillaries are active and they are allow the blood to flow through. Why is there a decrease at the bottom which one so the blood flow increases and then decreases here at the bottom okay. Let us see - it is anatomical - you see the lungs they taper there you know you get my point - it is like this it is not a round at the bottom it tapers okay so in the tapering part since the number of blood vessels are less, - therefore when you go further down - did you get the answer? In this part the blood flow is obviously so much, about much in middle and bottom when we say bottom we are here if you go further down okay since the since the lung tissue itself is not there, okay. Which one? This one. There is one more factor I do not remember - now I understand your point. We are talking of say per gram of lung tissue okay and your argument is that since it does not really matter why should it should be? I am forgetting I have dealt with this problem. I will tell you come on. You heard of leguminous plants okay they can fix nitrogen etc in their nodules you know which plant leguminous plants - they have molecule - which we call as leg-hemoglobin. I am sure you have heard of it, okay. Why do you call them as leg-hemoglobin because they are leguminous plant and those are very protein structure similar to hemoglobin molecule. It is a very old molecule where do you get the hemoglobin molecule in the animal world of course. You get it in vertebrates everywhere no doubt about it. But do you find them in invertebrates - the answer to that question is yes. Do you get hemoglobin in insects, yes. Do you get hemoglobin gene in amoeba yes okay. So it is a very old gene. It may be expressed may not be expressed okay. But it is a very old molecule - what am I talking about, hemoglobin. Secondly it is a there. No other word for it. Just a wonderful molecule and what we are going to do in another half an hour is just to understand the secrets as to why one of the great, absolutely stunningly great faculties of this molecule. It is the partial pressure around the molecule. Where is the molecule? It is in the RBC. Where is RBC? In the plasma. If the partial pressure of oxygen is more it will take. If it is less it will give. It does not need to be signalled or told by anybody. No it just the structure of the molecule, okay. So, depending on - if it is there it will take. Just as the RBC happens to pass through the lungs, okay - there is more partial pressure of oxygen it will take and from the lungs it will go to different organs. And where there is less oxygen it will just give. That is just what determines whether it is oxygenated or deoxygenated - just the partial pressure around, okay. And it takes - as the RBC flows through the capillary in the lungs, it can pick up all the there are millions of molecules of hemoglobin in a single RBC. Are you okay? Single I am looking at single RBC, how many I will tell you I have a slide there - there are millions of molecules of hemoglobin. As they pass through the lungs they all can be get saturated with oxygen within a within a period of 0.01 second. Hello did you get the impact - how much time does it take for an RBC - if you give sufficient oxygen to get saturated with oxygen how much time 0.01 second. How quickly because after all the RBC is going to take less than a second to zip through the capillary in the alveolus, okay. It is very short time even less than it takes even to get fully saturated. What am I talking about? Just try to appreciate the beauty of the molecule - the rapidity which it can it can get oxygen. So here we have the lungs and here is the capillary. In the capillary we take a RBC, from the RBC we go inside and we look at the molecule and we find that the molecule is made up of 4 units. We call them as 2 alpha units and 2 beta units. What do you call them as 2 alpha units and 2 beta units, okay. So let us talk something about - each is a huge globin molecule - globin molecule - 4 of them and the alpha unit generally has, I think about 141 amino acids - 141 amino acids and the beta unit has about 146 or 45 amino acids. Now let us briefly look at the structure, but before we go to structure, let us appreciate this very interesting diagram. Just focus on - you will enjoy this. At the top that curved thing - that basket like thing is the alveolus - are you done, okay. Below that the author has drawn for us a capillary. What is the length of this capillary 1 millimeter, okay. Less than that but not more 1 millimeter and the blood is arriving from here okay the blood is arriving from here and the blood is deoxygenated, hello, the blood is deoxygenated and the blood will have what partial pressure? There we have seen this yesterday tell me now much? 40 mm Hg. It is the blood that has been through the different organs. We are talking about the blood that has gone to the heart from the heart it has gone to lungs it has gone to this alveoli for oxygenation the blood has arrived is 40 mm Hg pressure. Good now as it goes from here to here what the author has done is that - you take sample here here here here here and find out the partial pressure of oxygen along the length of the capillary. And you find that as you go - as the blood arrives here what is the partial pressure 40 by the time the partial pressure goes goes goes by the time that single RBC comes to about this point which means about one third - the first length of the capillary - what do you find? There it has already reached top - which means what? About 104 mm Hg. Are you getting the argument? The RBC even much before it reaches the other end - it is already oxygenated can somebody can somebody try to speculate on what might be the rational of the nature in designing this way.

During exercise blood flow increases so the exchange should happen quicker. Exchange should happen quicker or quicker okay yeah. He has got absolutely correct answer. Let us see you have to suddenly doing exercise huge amount exercise so as a result of that your muscles are using huge amount of oxygen so in that particular scenario the blood that is going to the heart and from the head to the lungs is at the partial pressure 40 mm Hg. Now it might have gone to 30 it might have gone to 25 okay. So if the blood arrives here and if it is not 40 but 25 because of rigorous exercise, even in that case this curve may just, follow the finger, this graph may go that way - still margin so by the time - so even if you are doing exercise okay - it may be delayed slightly but by the time the RBC has gone 50% it is 100 definitely - it is saturated with oxygen, okay. So this is the safety factor which the nature has given okay. So, that also determines lot of things including the length of the capillary so look at the design from every point of view, okay. the diameter of the capillary, the thickness of the capillary wall, the rate at which the blood is flowing - and by the time it comes here, what is the partial pressure of oxygen? It is really 104 okay this tells us about what happens during exercise we just move on.