Human Physiology
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Lecture – 25
Excretory system : Kidney - Part 2

Do you remember what are podocytes? What are podocytes? What are podocytes? Everybody can talk at the same time, I will follow. What are podocytes? They are cells. They are cells, very good. Excellent, they are podocytes, very good, very good. Now what I will do is we are trying to address a very interesting point. The question is over a period of 1 minute, how much of blood flows through both the kidneys? And out of that how much is filtered? So how much is filtered, how much is not filtered? So the literature tells us that combined blood flow through both the kidneys is about how much? 1100 what? ML per minute.

So what I will do is I will take a jar, are you with me? Take a jar and in that jar I will put 1100 ml of blood. We are okay so far? And I will look at that blood and I tell myself that this is the volume of the blood that is going to flow through both the kidneys over a period of 1 minute. Now what I will do is I will centrifuge all that quantity whatever it is and as a result of centrifugation for 10 minutes then the hematocrit, you get that word hematocrit which consists of RBCs and WBCs and all the particulate matter which will settle to the bottom okay and the plasma will remain to the top. So when I do it for the 1100 ml of blood, I get the hematocrit of about 500 ml which is cells and about 600 ml of plasma that is about approximately ratio.

Are you with me so far? Generally 55 percent is the plasma and 45 percent is the hematocrit okay so far? Give and take 1 or 2 percent. So how much of plasma I have now? 600 ml, how much? 600 ml. How much? 600 ml. 600 ml. So over a period of 1 minute how much of plasma is flowing through the 2 kidneys put together?

So how much of plasma, plasma, how much of blood is flowing blood? Again go back. How much of blood is flowing through both the kidneys over a period of 1 minute? 1100. Okay. Now I am not going to talk in terms of blood, I am going to look at the same thing but talk in terms of plasma. So how much of plasma flowing through it? 600 ml.

600 ml. Good. How much of it is, how much is 600 ml of plasma out of that? So, out

of that 600 ml of plasma I find that the filtered amount, filtered amount is about 120 ml. Is about how much? So 600 minus 120 is the amount of the plasma that will just come and go okay and about 120 ml of plasma okay the liquid part I cannot call it absolute plasma because now that filtered part does not contain large proteins. Are you with me? So it contains but it contains lot of but how much quantity it is? It is about 120 ml per minute which is about 20 percent of the plasma filtered.

So out of 600, 120 that is 20 percent. Are you with me? So what is the message we have? Okay out of the total amount of blood that is total amount of plasma that is flowing over both the kidneys about 20 percent of plasma and I will call that as the glomerular filtration rate. Are you with me so far? What will I call it as? GFR or glomerular filtration rate okay. Now this is extremely important because this is actually filtration is happening okay. This is the filtration is happening and for that filtration to happen okay I have to make sure that the blood as it arrives in the Bowman's capsule should have the pressure of how much? 60 mm.

Very good. How much? 60 mm Hg. So to keep that 60 at the level of aorta I should have 80- 120, 80 - 120 when at the level of aorta it is 120. By the time the blood flows through arteries, smaller arteries, arterioles, da, da, da, finally it goes to the Bowman's capsule it has come to 60 where the blood is entering, the blood pressure is about 60 and at that blood pressure how much of filtration I am getting? I am getting about 120 ml of plasma per minute. Are you okay so far? Good.

Okay, so we will stop here and we will move ahead. Now let us see what happens to the filtrate. This is a cartoon that shows you the I am sure you can appreciate the nephron there. There is a diagrammatic view of the nephron and then you can see the blood is coming and the blood is getting filtered, plasma is getting filtered and whatever is unfiltered is going and then it is going into the so there is afferent arteriole, efferent arteriole, the peritubular capillary network and then it is somewhere here that the oxygen will be given deoxygenated and deoxygenated blood will flow into the renal, finally into the renal veins and renal venules. Good, good, good.

So again going back, just tell me what pressure do you expect in this vessel there? So, loudly everybody? 60 mmHg. 60 mmHg and how much of pressure do you expect in the vessel that takes the blood away from there? 59. 59, how much is it? 59. By the time the blood has flown through an enriched capillary network, it is in the what you call as a peritubular, the diagram we have seen yesterday, by the time it has come here the blood pressure has fallen to about? About less than that, about 15, 16, 20 that range the blood pressure is and by the time it goes here it has further fallen down to 5, 6, 7, 8. Remember these pressures.

Good. Now, this tells us something very interesting. Look at the number 1 there which is very simple and straight forward that is what? That is 20 percent of the GFR. Are you with me? Number 1 that is just the filter actually. That is the pressure of filtration that is happening. The fluid that is passing by the side of the podocytes and which contains all the small ions, small molecules, no large proteins and that line then by the time and then this is the rest of the nephron ascending, descending whatever let us not bother and then we find that lot of things are being look at the arrow number 2 very important that lot of things are being reabsorbed.

That means lot of things are filtered and lot amongst them are being what? Reabsorbed. Secondly, look at the point 3. Lot of the substances that are already in the blood which did not, which escaped being filtered there, they are being actively secreted from the blood into the tubule. So there are 2 avenues by which the substances in the blood can get into the tubule. One they can be filtered and the 2 they can be actively secreted at the level of what? Peritubular network.

It can be secreted into the tubules and then fourth of course is the urine that is. Now very simple, what you are getting at 1, whatever you are getting at 1, is it urine? It is not urine. It is actually filtered plasma minus large proteins, largely. That is plasma, it is still plasma. That plasma when it is being acted upon by the urinary tubule as it goes as you can see in step 2 and 3, there is lot of processing happening.

And then finally by the time it reaches the pelvis and the ureters that you get is a urine. So lot of processes are happening into the end that is what we are going to talk about today and in the next lecture. So lot of processing is going to happen. We will call this filtrate, many people like to call it as pre-urine. Do you get the language? It is something that will give rise to urine eventually, but that is not urine proper.

Now this is an interesting diagram that tells us as to how the kidney has got to capability of identifying different molecules and treating them separately. Every molecule has its character, has its personality. I can use that word. Every molecule has it and the kidney cells are able to distinguish them on the basis of so let us see.

Look at the one in A. The kidney is looking at the molecules which fall in the category A and they are the waste product like creatinine. Now creatinine, I am using the word again creatinine. Remember this word, it will come down two slides. Creatinine, what word did I say? Remember this word. A creatinine like substance which is a waste will just filter, will just go through.

Is it being reabsorbed? Look at the diagram and tell me. Look at, no it is not being absorbed. Good. Now let us go to B. In the B what do you have? The electrolytes.

The moment I say sodium, potassium, whatever, the electrolytes. Electrolytes are being filtered and then look at the diagram. Are some of the electrodes being reabsorbed? Are some of the electrolytes being discharged through the urine? Look at the figure C. In the C one, amino acids and glucose, look at the figure C. Are they being filtered? Yes.

Are they being absorbed? All of them. All of them. Why all of them? Because they are needed. Because you do not want glucose to lose. You do not want the glucose to be lost through urine.

If you do that, you are a diabetic. So you make sure that whatever is filtered, amino acids is filtered back and substance D is drug metabolites. We do not want them. And there are metabolites which are of course filtered.

They are small molecules. They can be filtered and those which are not filtered are actively secreted from the blood into the urine. So they are thrown out. The body does not want them. Are you with me? Now let us see as to how does the system deals with it in a quantity. Why is creatinine not actively secreted into the urine? Why is creatinine not actively secreted? It is shown as A which is just filtered but not secreted.

It is not the property of the peritubular. That is a good question. So the cells of the peritubular capillary are not equipped with a system to selectively secret that molecule, to secret the, actively transfer the molecule from the cells into the space and then and extra cellular space and then into the urinary tubule. It is not possible for the system to handle that molecule that way. So what it does is filter the blood again, again, again, again.

So let it be thrown out but only by way of the ultrafiltration at the level of the Bowmen's capsule. So let us see what is this table about. We are talking about different molecules. They are being filtered.

And let us see glucose. What is it grams per day? What about glucose? How much is the amount filtered? 100 grams, there is a lot of, lot of, where have we got 24 hours? How much both the kidneys are filtering? 180 grams of glucose. And how much has it reabsorbed? 180. All of it. All of it. If you are a diabetic, then it would be something less than 180 or whatever or because you have more blood sugar that 180 may be 280 depending on what graduation of diabetic you are.

Get my word, graduation, nobody smiled. Then you have so zero. A bicarbonate 4300, a little is excreted. Sodium 25000 something, reabsorb 25, about 150. So some, is there some sodium now? Now look at sodium.

Sodium 25000, 150 is excreted. Now go back to the experiment which we did yesterday. When you do the experiment, you suddenly your sodium intake was what? Was what? Was increased by tenfold. So what would happen there in this particular case? That 25000 will go, 25000 will go to I do not know 50000, 60 or whatever. The amount reabsorbed will be very low. Hello? Whereas the amount excreted from 150, it may again go to 25000.

I do not know the figure. It will be very high because now your kidneys making sure potassium urea and then let us go to again creatinine. I will come to that in next slide. So this amount filtered is 1.8 grams per day. Nothing is reabsorbed. Whatever is filtered is completely thrown out and therefore amount excreted is 1.8. Now let us talk about creatinine.

Listen to this. This is interesting. Particularly two organs of our body, namely the skeletal muscle and the brain. These are again two of the very expensive organs. Expensive in terms of what? Energy.

ATP. ATP is very high. Now let us focus on muscles. Now muscle, the moment you are taking rest and then you start exercising, see the amount of, you see every cycle, when I mean by cycle, I mean actin-myosin cycling. Are you with me? Actin-myosin cycling. With every cycle you are going to use one ATP.

One ATP every cycle and there are thousands of them. So your utilization of ATP is very high and it is not possible for mitochondria to supply all that ATP at the speed at which you are using it. You get the problem. Therefore, the nature has come up with an amazing solution and the solution is that these two organs are equipped with yet another molecule called as creatine. What was the earlier word I told you? Creatine.

Now I am telling you a new word. What is the word? Creatine. So the creatine word, creatine molecule has an interesting property that it can easily get phosphorylated. It can easily, so it becomes what? Creatine phosphate. What does it become? Creatine phosphate.

It becomes creatine phosphate. Good, good, good, good. So whenever you are resting and whenever you are not, there is not much burden on your ATP supply, the creatine becomes creatine phosphate. So you have sort of reservoir. Are you with me? You have

a sort of what? Reservoir. Reservoir. So you are exercising and the moment your need for ATP suddenly goes up, that phosphate, that phosphate, okay, let me go back.

So you are suddenly doing exercise, so you are using ATP and you are giving ADP. ADP is there. Now suddenly too much ADP is there, you are exercising. Are you with me so far? Now suddenly that ADP will take that phosphate from creatine and itself become ATP. So what has become now that creatine phosphate has now become creatine.

So that creatinine molecule is a very loose bond. It can take phosphate, give phosphate, take phosphate, give phosphate depending on the availability. When it is available, make yourself creatine phosphate. When it is in poor supply, give it away to ATP, ADP, make it ATP so that ATP can again is available for muscle contraction to take place. Are you with me? Now when so that is what is happening, creatine, okay, ATP, ADP, it is a reversible reaction and it is converted to phosphate. So your phosphocreatine never mess up, is a buffer, is a reservoir for.

However creatine phosphate over a period of time that molecule, you see in biology everything breaks down. And finally when it breaks down that molecule is called as creatinine. What is it called as? So creatinine molecule eventually it comes, it serves and it breaks down. When it breaks down that new form of molecule is called as what? Say that again, creatinine, say that loudly.

Creatinine, okay, we are not going to mess up. Creatinine, creatinine, I am sorry creatine is very useful. Now creatinine is a relatively waste molecule, okay. And therefore when it is filtered, it is not reabsorbed, we want to get rid of it, okay. So, we are not going to get rid of it, but there is continuous, our body is continuously generating, it mean and we are continuously using it and we need to, we are continuously throwing it out of our body, okay. As a result of that, I am going to ask you a question, beware of that.

As a result of that, I take your blood sample, it is a critical movement and I find that and from the blood I separate serum and I subject that serum to analysis of creatinine and I find that your concentration of creatinine is can be easily for me? 0.7 to how much, how much, that is a limited range. Okay now I am telling you something. Anytime you see blood, pathological report of anybody including yourself, okay and if you have just do random sample, I am absolutely sure the pathologist is going to report on the creatinine in mean level in your blood, okay.

Make sure that it falls in this range. Now, if you find that this is creatinine in a

particular report is exceeding going to 1.4, 1.8, 2.8, it means what? It means what? Kidney is not working properly.

Kidney is not working very good. It is, its efficiency in getting the clearance of creatinine is going down. But you are absolutely correct. The kidney is a problem. Are you with me? Okay, why am I hammering this on you? The moment you see anybody's blood report, anybody's blood report, okay, I want you to go to what parameter? And look for what? Level.

Level. And make sure that it is in what range? 0.7. Anything more than that, okay, the bell should start ringing that there could be something wrong with the kidney. We are back to our problem of filtration of blood and I am sure you can appreciate we have the Bowman's capsule there, the glomerulus is there and the author has taken a tiny rectangle from there which is one of the tiny part of the capillary, okay. And then the author has blown it up for us and then we are actually focusing on what is happening during ultrafiltration. And we find that the blood that is arriving over the capillary is at about we have already done it, we have already done it, we have already done it, what is the pressure? 60.

60 what? mmHg. 60 mmHg, okay, about 60 mmHg is the blood available, it is under pressure. But the question is, is the blood actually being filtered at that pressure? The answer to that question is no. The answer to that question is no. Why no? Because in the blood there are proteins and those proteins have osmotic pressure and as a result of that those proteins are drawing water from outside. Are you with me? Is it distilled water there in the capillary? No, there are large number of protein molecules and they will themselves exert what? Osmotic pressure and why in what way it will attract water, okay.

As a result and how much is that is, how much is that? It is called as plasma collide osmotic pressure, it is also called as oncotic pressure, oncotic pressure. What is oncotic pressure? It is a pressure created by the proteins in the blood because of which it will draw water from outside, from outside into the capillary to draw the blood because of osmotic, large number of protein molecules there. And how much it is? It is quite large, how much it is? 32, it is taking the, it is acting in opposite direction therefore authorized what sign? Negative. Negative, minus.

Secondly is this, you see on the other, this is the capillary. Outside the capillary there are podocytes and outside that there is space and there is fluid there. So that fluid is also exerting some pressure, okay. That pressure is called as capsular hydrostatic pressure. What is it called as? Capsular hydrostatic.

So the filtration has to take place, okay, against two forces. Number one is the oncotic pressure and number two is what? Capsular hydrostatic pressure which comes to about how much? People have calculated it about minus 18. So effectively 18 plus 32 is 50, that is subtracted from 60. So the effective pressure at which the blood is being filtered in the kidneys how much? 10. Only 10, only 10, that 60 can be deceptive.

It is not at the pressure of 60 mmHg that the blood is being filtered. The effective pressure is how much? 10. 10 mmHg. Now starting there is 60. Now imagine you have a patient.

With a low BP and the pressure instead of being 80 -120, okay, it is 70 -100. Are you with me? By the time the blood arrives, okay, at an afferent arteriole is about to enter into the Bowmen's capsule, it has already fallen to 45 -50. If it has already fallen to 50, the effective pressure may be 2 mmHg, 3 mmHg. Is it good enough? It is not good enough. It is not good enough, okay, because the nature has provided a very little margin just 10 mmHg is the effective pressure available in a healthy kidney. Therefore, the point that I want to hammer is low pressure can be dangerous because if it falls here, the urine formation will stop.

Are you with me? And now you know why the urine formation will stop if the blood pressure falls below a particular limit.

Kidney is such a, yeah. Sure, sure. It is a, okay, it is a cup. It is a cup. Now, the cup has two walls. Are you with me? The in the inner wall, in the inner wall, we have a tuft of capillaries, okay, and they are continuously, the filtrate is coming. The filtrate is going where? The filtrate is going, the filtrate is going in this yellow space here. The filtrate is going in that yellow space.

It is continuously receiving the fluid and it is flowing, but the fluid is still there. Whatever is the fluid there, at any given moment, it exerts certain pressure. Done? Right. So, where was I? Okay. So, the point that I want to make is that 10 mmHg is the effective pressure.

Okay, okay, okay. I certainly remember what I wanted to. Sir, earlier you mentioned about during the Starling hypothesis, the blood entering the capillary was at 30 mmHg, but still fluid moved out because the external pressure was lower. But here, why is the combination of osmotic and hydrostatic pressure more than 30? So that, why is it more cured there, it is less? Why is it more here? It is more here because this is a bound volume. Okay, this is a bound volume. It is bound by the parietal membrane of the

Bowman's capsule.

Relatively in the capillary, it is relatively an open space. Okay, so it is much more easier for the pressure to dissipate there. Here it is not possible. Yeah, sure, sure. I will talk to you later again if necessary. The answer to that question, why is the person sick in the first place? Are the angiotensin II is there, but the receptor is not there? There are 100 reasons possible because of which the, because you gave, because so you do not know what has gone wrong, but you have the patient and you see the blood pressure and you see that the urine formation is not good enough or whatever.

Sir, not every blood pressure patient will suffer from. Oh no, no, that. How is it possible? Human body is so complicated, 100 things can go wrong. It is just not possible. It is just not possible. Ask a doctor, he will tell you every patient is unique.

Now here is an interesting pathological case. We have all heard of kidney stones, kidney stones, okay, as a result of something going wrong with the calcium metabolism, then calcium precipitates or urates precipitate and you have a stone formation and here is a diagrammatic picture in which you can see one stone there in the medulla, one stone here in the pelvis and one stone. Look at this nasty stone which is sticking right at the mouth of the ureter.

What will happen? Obstruction. Obstruction, very good. Step number one, obstruction. Step number two? Yeah, the ultrafiltration is happening, okay. So that hydrostatic pressure will go up. Hello, are you with me? That hydrostatic pressure which was about what about minus 18 or so, am I right there? That pressure will go up because the fluid is coming and there is no way to go, okay. As a result of that 18 will become 28, it may become 38 and as a result of that ultrafiltration will stop.

Are you getting the argument? And this could certainly be a very emergency case, okay. The stone, if the stone just sits there and just obstructs the passage of urine, okay, it could be a very serious condition because and there is a picture of you can actually literally show the, see the stones there, okay. Thank you.