Human Physiology
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Lecture – 11
Cardiac system : From stimuli to rhythmic muscle contraction - Part 2

The aim of this slide is just to focus on the valves. So this is the bicuspid valve or the mitral valve we are talking of the left ventricle and this right ventricle when both of them contract you better close the bicuspid valve here, the tricuspid valve here, making sure that the blood flows from the right auricle into the pulmonary artery so that the blood will go for oxygenation and from the left ventricle it will go into the systemic and it will go to the rest of the body. So valves, valves, bicuspid valve, tricuspid valve, semilunar valve, semilunar valve are you okay with me? okay. Now remember this and we will move on to the next I am going to ask you to focus. This is a very interesting animation, very interesting animation. Okay now just for 5 minutes let us ignore, let us ignore what? Let us ignore the right auricle and the right ventricle. It does not exist, what exists for us right now is only what and what? Left ventricle.

Okay, okay. Now the left auricle, the left auricle is receiving blood, left auricle is receiving blood. It is receiving blood through - look at the image and tell me how many vessels are pouring their content or the blood into the, into the left auricle? 4 - 2 from the left lung and 2 from the right lung.

Okay and you can see there are, there are 2 arrows here, there are 2 arrows here and then those 2 arrows are pouring their blood and when they pour then this, then the valves open and then the blood goes into the, goes where? Okay, great. And then, and then, when this left ventricle goes into systole, are you with me, when it is contracting, okay, then this has to close and this has to open. Just follow carefully, am I right there? Yes or no? Okay, now I will tell you, I will ask you something very simple. Keep an eye on this, keep an eye on this.

This closes, this closes and this opens, again this closes and this opens and there is a very tiny, tiny gap of about 0.02 seconds there. Hello. See that again, what am I, I am making very interesting point, don't miss the point, what am I saying? This closes, this closes and this opens. But these 2 events don't happen at the same moment, that is my point.

Are you okay so far? So there comes a tiny period, if you actually measure the time period in the heart, it is about 0.02 seconds, how much is it? 0.02. 0.02, say that again, how much is it?

02. So during that 0.02 seconds, the left ventricle is a completely closed chamber. Hello, nothing is coming in, nothing is coming in, nothing is going out, are you with me? I am talking of what, that tiny period, what is the length of that period? Yeah, yeah, that is the period, that is the period, okay. When it is a closed chamber, it is a closed chamber. At the end of that, at the end of that, then suddenly this will open and the blood will gush out into the aorta. This tiny period has great significance, therefore I am emphasizing on it, is called as a period of isovolemic contraction.

What did I say? Why isovolemic? I think you can immediately make out the sense why isovolemic? Because volume has not changed, because volume has not changed, okay. But during that period, during that tiny period, although volume is not changing, the muscles are undergoing a tremendous contraction. So if we just measure the pressure, the pressure has greatly increased, the pressure has greatly increased, but volume has not changed, okay. And as a result of that, what would happen if you suddenly open the semilunar valve? You have applied a pressure, you have applied a lot of pressure, and everything was closed and suddenly you open the valves. The blood will gush through the, into the aorta with the pressure of 120 mm Hg.

Are you getting it? How do you attain 120, 120 in a gush? So you process, so actually when you are, okay, okay. What is the pressure like of the blood in the ventricle, in the ventricle when the blood is coming from the auricle? What was the pressure in the auricle? We talked about the thing in fact. Very, very low. And if that blood under low pressure in the ventricle has to go into the, I am sorry, from the auricle has to go into the ventricle, what should be the pressure in the ventricle? Very low, very low, it is very low. Otherwise it won't go, if you want to drive the blood from auricle to ventricle and if the blood pressure in the auricle itself is low, it has to be low because the pressure in the, on the venous system is low.

Therefore the whole system is extremely low, extremely low in such point that the ventricle is going to be low. It has to be extremely low. So, so, so when the blood is flowing from the auricle into the ventricle, the blood pressure in the ventricle is extremely low. And then suddenly for a period of 0.02 seconds all the valves are closed and the heart goes into the systole and it contracts and it contracts.

It generates pressure, it generates pressure from almost 0 or 1 and the pressure goes to 80 mm Hg. It goes to what? 80 mm Hg and only when it reaches 80 mm Hg that these valves open. Means what? Means what? Follow the story, where are you? You are sitting in the ventricle. Which ventricle, left or right? You are sitting in the left ventricle and you are just watching and you are seeing that the ventricle are relaxing and the pressure here.

Okay. Then suddenly the valves close, and then you suddenly find that walls of the ventricles are in a process of contracting, massive contraction. And as a result of that the pressure is increasing. But all the valves are closed, okay. So, the pressure goes on increasing, increasing from 0, from maybe 1 or 2 to 10, 20, 30, 40, 50, 60, 70, 80 mm Hg. The moment it reaches 80, this valve opens.

So, what is the peculiarity of that valve? What is the peculiarity of the valve? The strength of the peculiarity of the valve is its ability of the, the ability of the valve – you need to appreciate the anatomy of the valve. The pressure does not fall below 80. So, the semilunar walls do a very interesting function of making sure that although on the side of the ventricle, the pressure may fall to 0 or 1 or 2 mm, during diastole. On the other side, on the aorta, the blood pressure will remain 81, 80, 81, 80, 81, 80. Again, let us follow the story.

I will put you in the ventricle. What is the blood pressure like 2 mm Hg? What is happening? The blood is arriving. What are you doing? You are expanding. The blood is coming from here, from the left auricle.

You are full. You are full. And suddenly both the valves are closed. Then you start contraction. Once you start contraction, all the valves are closed. You go from 0, 10, 20, 30, 40, 50, 60, 70, 80.

The moment it happens 80, the semilunar valves will open. And the blood will go, but the heart keeps on contracting. The heart keeps on contracting till the blood pressure from 80, 90, 100, 110, 120. And then once it reaches 120, then the ventricle will start relaxing. And the pressure will go all the way from 120 to almost 4 or 5.

Because then it is now ready to accept the blood from the respective auricles. You will follow the entire sequence of events correlated with the pressures. Because the pressures are different because the pressures are trying to relax. Done? Good, good. Anything? How the pressure is maintained? The pressure is maintained because? If you are sitting in the aorta.

Now I will make you very small and I will put you here. Very small. What are you experiencing? You are experiencing that every 0.8 sec. Every 0.8 sec the blood is, the door is opening, the valve, the door is opening and the blood is coming. The blood comes with the pressure of 120 mm, 80, 90, 110. Anything in the range of 80 to 120. And then the blood flows forward and then it drops. Once it starts dropping below 80, the doors will fall to whatever - you do not care. You are there in 80. Now the question is why does it remain 80? That is the question. I do not want to talk about this now.

The wall of the aorta. Follow this, this very interesting point. Let me see if you can, I will just make a statement and let me see if one of you can explain the meaning of that pair of words. Show the phenomena of compliance. The wall of the, it is a tube. Aorta is a tube, okay, it is a tube.

Shows the phenomena of compliance. Okay, what is this, this is diameter. What is this? This is a section, this is a section, through what? Section through the aorta. Okay, are you with me? Okay, now the, if I go back I have the valve and if I go back I am in the left ventricle. Are you okay? This is the diameter. Now suddenly the ventricles have gone into systole.

Up to 80, I do not experience anything. The moment it goes above 80, the valves open. Once the valves opens then I suddenly find that the pressure inside has gone from 80, 80, 90, 100, 110, 120. What is happening to the diameter? It is increasing. It is increasing because of the pressure. Okay, now after a very short time the valves are closing, the ventricles are going into diastole. So the pressure in the ventricle is dropping. From 120 it is now rapidly going to 110, 100, 90, 80, it has gone below. But the moment it is 80 the valve will close. The moment the valve will close, you got the message? So the aorta shows, aorta acts like a buffer you know.

It takes the pressure, once it takes the pressure it expands, it is elastic, it is elastic. It is not a hard metal water pipe. Okay, it is elastic. So when the blood comes, it expands, accommodates lot of blood. But as soon as the valve is closed, then it closes so that it maintains the pressure down the line as the blood flows away from the aorta into the different branches.

Got your answer? Another lovely animation. It is just fun to look at it, okay. Can you identify that, we are just looking at the ventricles, okay. This is the left side, this is the bicuspid valve, this is the tricuspid valve. And on the, on the, okay now let us get the anatomy straight.

This is the valve. Okay, the edge of the valve I will call as the V-A-N-E, V-A-N-E, not V-E-I-N. Are you with me? And on the edge is attached a thread, okay. It is a ligamentous thread, it is a thread. I will not call it a thread, I will call it as chordae tendineae.

What will I call it as? chordae tendineae. That chordae tendineae goes down, that chordae tendineae goes down into the ventricle and in the ventricle, now I am looking at the inner wall of the ventricle. The inner wall of the ventricle is not a, is not like, not a smooth surface like that of a glass or a cooking vessel that we have. But on that there are certain, there are certain muscular projections. Hello, are you with me? A muscular projection on where, on the inner wall of what? The ventricle.

Okay. It is muscular, it is cardiac tissue, it is cardiac tissue. Okay. And I will call them, I will call them as the papillary muscles. What do I call them as? Papillary muscles.

I will call them as the papillary muscles. What is a papillary muscle? It is a cardiac muscle, sitting there in the papilla. Sitting there in the what? Papilla. Papilla. Okay. Now that chordae tendineae cauditendini, that ligamentous thread, okay, what we will do one day is, we will do a lab session.

Okay. Here in G1 we will do a lab session. In the lab session we will take a look at the heart of a goat, which I can get from a slaughterhouse. Okay. And the aim is to see the heart and the aim is to show you the chordae tendineae. Okay. And the aim is to show you how strong the chordae tendineae.

Okay. If you pull and, if you pull the chordae tendineae with your finger, okay, it is very hard to break. Okay. It is like a thread. Chordae tendineae.

It is very strong, very strong. Okay. And it, so one end of the chordae tendineae is anchored on the vane and the other end is anchored on the papillary muscle. Now every time the blood enters, now get the story, every time the blood enters into the ventricle and the ventricles go into systole, the pressure suddenly increases and that pressure, which will almost go to 120 mm Hg, it is going to pull the valve, it is going to push the valve and the valve themselves are very thin, film like, valves are thin, valves are not muscular, these two valves are not, they are very thin. And there is a possibility that under the pressure of 120 mm Hg, the valves will simply flip open and the blood will go back.

You do not want that to happen. Okay. Therefore, you want to hold them with a rope. Are you with me? You want to hold them with a rope. That is exactly the idea. So who holds them with a rope? Chordae tendineae. But you need to make sure that chordae tendineae themselves are very strongly anchored.

So they are anchored on what? Papillary muscles. Okay. Now, now here is a problem for you. Here is a problem for you. There is a patient, okay, that patient has a problem, heart problem. What is the problem? Well, the heart itself is supplied by coronary blood vessels, I am sure you have heard of it.

Hello, Coronary? What is coronary? It is a blood supply to the heart. Okay. I will talk about coronary blood supply also. But right now just to tell you that there is a blood supply to the heart muscles, which is coming from outside.

We will talk about coronary. And one of the branches of the coronary is going to the papillary muscles. Imagine, imagine that the capillary or the blood vessel that is going to the papillary muscles is ruptured. Okay. What happened to it? Ruptured, it is ruptured.

So are the papillary muscles getting their supply of oxygen? No. What will happen to papillary muscles? They will die, they will die, they simply die. If they die, will they contract at the proper moment to make sure that the bicuspid valve does not flip on the other side? Will it do its function? It will not do its function. Because it has to hold, it has to contract and make sure that the vane remains in the proper position so that the valves are really, fully closed. That function will not happen. Then what will happen? The blood will go from the ventricles into the auricle.

Are you getting the problem? Very serious problem. Okay. Okay, with every beat, the blood which should not go, should never go from the ventricles into the auricle, but if the papillary muscles are damaged and if the chordae tendineae are not able to pull the vanes of the valves properly, then the valves will leak and the blood will go from the ventricles into the auricles. I give this example only to stress the importance of what? Great. Can you see this white line in the middle here? This I will not talk about it now. We will talk it maybe in the next lecture.

This is the conducting system of the heart. You just remember these three words which I am telling you. What system is it? Conducting system of the heart. I will talk about the conducting system of the heart. So the blood from both the auricles will come here and then it is being pumped into the ventricles.

There is a very interesting graph here. We are going to study what you call as the cardiac cycle, which repeats every 0.8 seconds.

Therefore you have 72 beats in a minute. Done. And therefore every 0.8 seconds, the blood has to be pumped out from the ventricle into the aorta and from the right side of the heart into the pulmonary.

It has to go. Good. So these are the various changes that are happening in a single cardiac cycle. Look at the x axis. What do you have here? We have time here.

We have 0. 0 means what? We are beginning. We are at the beginning of a cycle. How many cycles are we going to have over a period of minute? 72. How many? 72. We are at the beginning of the cycle.

And we are going to follow a cycle from 0 to about how much? 0.6, 0.8. 0.8 seconds. And this will tell us about one cycle. If we have read one cycle, we have done all the cycles.

So we are going to focus on one cycle. Done. Good. Now what I will do is this side. Actually, there are a lot of changes that we are going to study across the cycle. Why are there so many parameters? What are the different parameters? We have the pressure in the ventricle, pressure in the aorta, pressure in the auricle, the volume of the ventricle, and the ECG.

Hello, I am sure you have heard of electrocardiogram. So a lot of factors are here. Out of that, I am going to currently focus on. Currently focus on. I will deal with several factors, but right now let us just focus on pressure changes in the left ventricle. What did I say? I can also do that with the help of - try to monitor the pressure changes in the right ventricle.

I can do all that. But right now to make life easy, we are going to focus on what? Pressure changes in the left ventricle. So what I will do now is I will take a very tiny pressure sensor. I will borrow it from physics laboratory.

Very tiny, tiny. And I will plant it in the left ventricle. Are you okay? I have done it. It is there. And it is recording it and by some remote mechanism, it is also giving me information as to what are the pressure changes that will happen over every cycle. And I find that and record, and my record, this blue line here is my record. How do I get the record by that pressure sensor, which I have implanted, which is sitting where? Sitting where? Left ventricle.

And I will monitor the data generated, it is generating data. I will monitor the data generated over a period of one cycle. And I find that at the beginning, at the beginning, and the pressure is, pressure is depicted on the y axis. And here I have the pressure in the ventricle, which is where am I? If this is 0, then maybe 1 or 2 or 3 mm Hg is the pressure in the ventricle at the beginning of a cycle. We have done that already. And that pressure better be in a very narrow, very small, very, very small range, then only the blood from the auricles will flow into the ventricle.

So it is very low, it is very low. Now look at the first arrow, ventricular systole begins, look at that arrow, what does it say? Ventricular systole begins, now the ventricle fully stretched, it has taken all the blood, the blood pressure is very low, and now it is ready to contract, which means it is going, it is ready to go in systole. As it is ready to go in systole here, the blood pressure rises. The blood pressure rises, the blood pressure rises, look at this dotted line and this dotted line. Please again look at this dotted line, where what? Step number 1, step number, the ventricles have started going, this systole means my pressure transducer is telling me from, it was originally 2, 3 mm Hg, 5 mm Hg, 10 mm Hg, 20 mm Hg. When that is happening, I am actually in the period of, read for me, that is the period when both the valves are closed and ventricle is a closed chamber.

And as the pressure that is being recorded by my transducer there, it goes from here, here, here to here, which means about how much? Then the aortic valve, semilunar walls are going to open. Are you with me? And then it will open and the blood will go as far as how much? 120 mm Hg. Are you with me? Now, by the time it goes to 120 mm Hg, my systole is coming to an end and the ventricle is now ready to start relaxing. It will start relaxing.

But as it starts relaxing and the blood pressure falls, it is going down. Something another very interesting thing happens. Again both the valves are closed and I have a phenomena in which now the ventricle is relaxing and I call that phenomena just opposite of this, I will call it as what? Means what? Means what? The left ventricle is a completely closed chamber. All the valves are closed, but the ventricle is under diastole and it is relaxing. And as it is relaxing, the blood pressure will fall and somewhere at this stage, when the blood pressure is about 100, the valves, semilunar valves which had opened now closes. As a result of that, the blood pressure on the aortic side remains high, whereas the blood pressure on the lower side, on the ventricular side falls.

It rapidly falls to about almost 1 or 2 mm Hg and now this ventricle is ready to receive the blood from the auricles. Are you with me? Very interesting things are happening. Again we have to be very mindful of the point where the two valves, one that is allowing the blood to flow from the auricles to the ventricles and the other system which is bicuspid valve which is film like, which is equipped with chordae tendineae and papilla and the other system which is semilunar valve, there are no chordae tendineae in the semilunar valve. They are muscular walls and when they close, the blood will flow. I will draw your attention to the same image, I am sure you can identify the same image has been magnified here.

Hello, are you there? And this is the same image here. This is your understanding, author has given a bigger version. But that image, if you see the lower part, these two diagrams here, they just tell us as to when the valves are open and when the valves are closed. And the overlap, and the overlap, and the overlap, can you see the overlap here? Can you see the overlap here? What does that overlap mean? Isovolumic contraction, isovolumic relaxation means that also is also closed, that valves are closed as a result of that isovolumic contraction. Or opposite of that will be the phenomena of isovolumic relaxation. This is actually very simple. When the, very simple question, when the heart is in systole, the volume of the ventricle is increasing or decreasing? No question, it is decreasing.

It is systole, it is systole, the volume is increase or decreasing? Decreasing. Decreasing, what do you mean? It is decreasing. It is? Decreasing. Decreasing. The volume is what? The volume is what? During isovolumic contraction, the volume is constant.

Hello, hello, hello. But then when the systole, the volume is? Decreasing. Decreasing, correct. Then in diastole, you need to accommodate the blood. This tiny red dotted curve tells you about the, we talked about that tiny sensor, where did we plant it? Where did we plant it? Left ventricle. Left ventricle, I will put it in the left auricle. And then I will draw the graph and my graph is represented by this dotted red line. So the blood is coming in, hardly look at, look at the, so the, I will ask a very simple question, why are the muscles of the auricle much, much, thinner or weak as compared to the muscles of the ventricle? What is the pressure range they have to deal with? What is the pressure range? You look at this red dotted line and look at the scale there, what is the pressure range in which the muscles have to cope up with? 0 to how much? Not even 20, maybe 15 or so, very, very, very low pressure, very low, generally less than 10.

So as the blood flows, as the blood flows into the auricles and then the auricles contract, there is little increase in the pressure. Hello, we are talking about auricles. What about auricles? The auricles also go in systole for that last 25% of the volume, that goes there. And then when the ventricles go in systole, they also have some backward pressure, although valves are there, there is a backward pressure, therefore the auricular pressure slightly goes up. And then when the auricles finally receive the blood from the rest of the body, again there is little increase in the volume, so here you get pressure, so here you get, you do get minor changes across the volume, across the pressure changes in the auricles in each cycle that is depicted in here.

Now, see this red dotted line, I will talk about it and I will conclude my talk today that red dotted line, the upper one, upper one, that is if you are going to put the pressure transducer in the aorta. Where are you putting it? Aorta. Above the semilunar valve. And therefore, you are in a place where you will, you will never experience pressure less than 80. And that is being shown by this red, so it goes down as 80, again it goes to 120, then it falls to about 80 mm Hg.