Biomedical Signal Processing
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Lecture - 03
Biomedical Signal Origin and Dynamics

Now, we will look at the Biomedical Signal Origin and the Dynamics.

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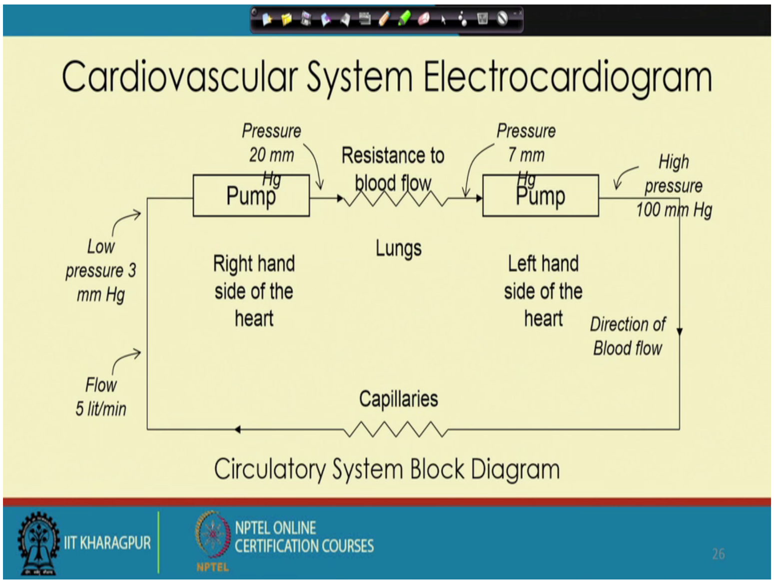

So, first let us look at the cardiovascular system and electrocardiogram. So, as a part of it let us look at that the cardiovascular system. It acts a set of pump that two pumps are there: one is a strong pump which actually gets the blood at the 7 milli meter mercury pressure, and it is we said that a high actually pressure of 100 milli meter mercury pressure. And it discharges it throughout the body from head to the blood is flowing and there are different branches, the arteries is actually takes the different parts of the body and then it branches out in the capillaries so that it reaches that every cell. And from there again it is getting collected through the capillaries and that it is through the branches it is getting collected in the veins. And it comes back again with a smaller pump, which gets it that a very low pressure of 3 milli meter mercury head pressure and accumulates there.

And per minute if you look at the flow rate is approximately 5 liter and here in this process that what is the job of this smaller pump; this pump actually is again increasing the pressure up to 20 milli meter head of mercury and it throws the blood to the lung. Where, the exchange of that oxygen and carbon dioxide takes place. And from the lung we get that the blood, which is rich in oxygen it comes to that second pump or the stronger pump.

And in this process this that arteries and that veins they also takes place, they are not just sending the carrying the blood this veins they also have some actually valves within that. So, they help to the unidirectional flow of the blood, but for the actually that arteries there is no such valve because, the pressure is much higher it automatically gets transmitted.

So, that is the difference between the arteries and veins, I think in the next picture we can get that in a better way.

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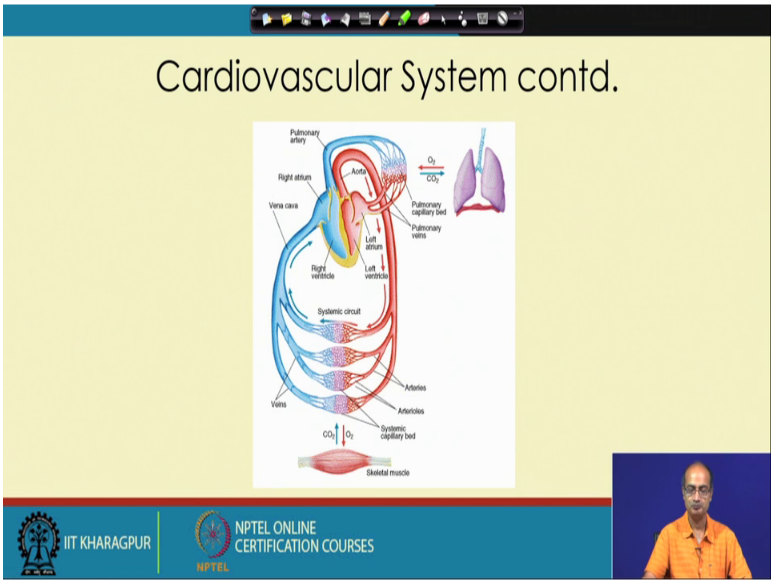

Here we see that the heart is here and the small pump actually what we told it is called actually the atrium. In fact, atriums have 2 chamber these chambers they are actually that if you look at that the exact flow, that right atrium that gets the that part that it is the veins are actually supplying the blood to the right atrium, right atrium actually discharges that when they are contacting the both the atriums right and left atrium and both the ventricles they actually get compressed simultaneously. The two left and the right atrium they actually get contacted at the same time, when they get contracted the blood from the atrium flows to the ventricles which are just below them and the atrium they have very thin muscles, because the they need to just push the blood below which is just adjacent to it; it does not need much power or much pressure.

Once the blood actually gets accumulated in the that ventricles, that ventricles then they get compressed and from the right ventricle it pumps out the blood sends it to the lung, where that carbon dioxide is released and the oxygen gets in within the blood and the oxygenated blood come into that left atrium. So, the from the left atrium the oxygenated blood comes in that left ventricle and left ventricle pumps it out throughout the body. Now if you look at the ventricles the construction of the ventricles they have much higher level of muscles or more amount of muscles than the atrium. And among these two the left and the right one, the left ventricles are much more stronger, because they need to give the blood distribute the blood throughout the body and it need to actually also take care of the fact that some of the organs like head, they are much higher above the that where the heart is located.

So, they need to overcome that gravity. So, that is the way you can look at that the circulatory system and that is the mechanical part of it we can say.

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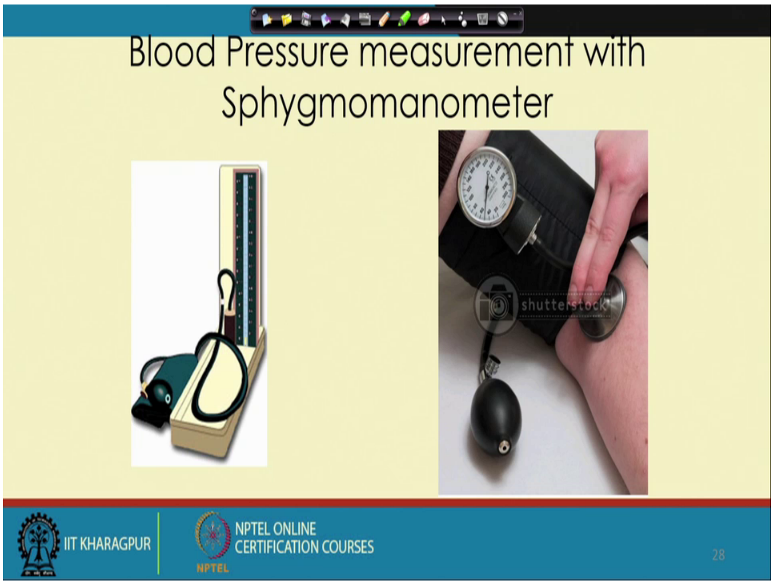

Next let us look at that how we can actually measure the activity of the this cardiovascular system, we told that there is a change of pressure and there are actually 2 pressures the doctors talked about, one is systolic pressure and the another is diastolic pressure. So, long the ventricles they are pumping out the that blood the pressure is high that is called the systolic pressure, when the ventricles they are not actually pumping out the blood actively that time the pressure in the that arteries that is called the diastolic pressure.

Now, the question is how we can measure that pressure. So, usually we see that sphygmomanometer which they can actually detect the pressure and the principle is very actually easy, here is the mercury column which indicates mercury column or the dial that indicates that what is the pressure change and there is a actually small pump, through which we can actually pump the that the air and it is connected to a actually that there is a band cuff band. And the cuff band is we wind it on the arm and there through that pump, we actually inflate that that band. Now as we keep on pumping it slowly the pressure builds and as the pressure builds what happens that when it goes above the systolic pressure, then that the blood actually circulation now completely gets actually stop through the veins passing through this limb or this hand.

So, now after going through a sufficient high pressure, that when the blood actually circulation stops. After that using this that the air is slowly released; that means, the pressure within this that cuff band that is slowly decreasing and first what happens that the moment it comes below the systolic pressure, the little amount of blood starts flowing and because the resistance is there that is the due to the compression provided by this these band. Now this 1 makes actually the flow of the blood turbulent because, for the whole cycle blood cannot flow that pressure is just below the systolic pressure, but above the diastolic pressure.

So, only for a very small part of the time or small part of the cycle the blood can flow and that flow is turbulent and because of that a sound is actually generated and we can pick up the sound with the help of this stetho. So, that first observation that nurse or the doctor would make that. Once the we put the pressure high there is no sound because there is no blood pressure, when you start releasing the air through this bulb then at some point suddenly we can hear some sound and the sound is called crocus sound. As soon as we actually find that sound audited that sound, the doctor will look at that in the dial or the mercury column and note that what is the pressure measurement that gives actually the systolic pressure or the highest pressure within the veins.

Then we again keep on releasing the air but very slowly, at some point we find that that when the pressure in this actually this inflated band, it goes below the diastolic pressure then there is a no obstruction provided actually to the flow of the blood.

Now, throughout the cycle the blood can flow through that vein. So, till that point that crocus sound actually continues the moment, it comes below that diastolic pressure that sound is stopped because, the floor becomes laminar it is no more turbulent so that when the point that the sound stops. Again the doctor marks that what is the reading in the dial or the mercury column and from that we can get what is the diastolic pressure. So, that is the way the doctors can check your blood pressure. So, that is an important part of the circulatory system.

Now next we look at the other aspect of the circulatory system. Now, let us look that how actually this blood flow is controlled, when you look at the heart we have 4 chambered.

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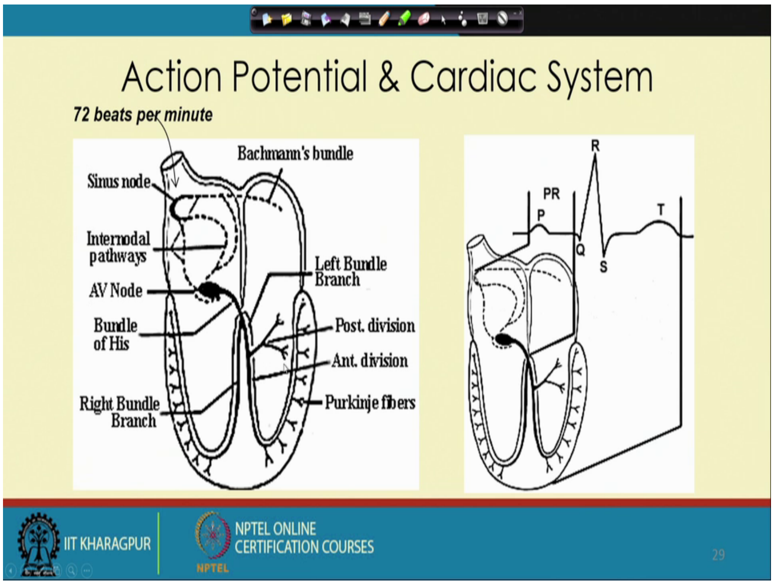

As we told you that we have the at the top we have the 2 chambers they are called the atrium and below we have the ventricles and we have a we need to have a synchronous actually movement of or synchronous compression of this chambers for the proper flow of the blood, we know that the upper right chamber or atrium that collects the blood coming from the veins, which are rich in carbon dioxide and they are supposed to actually give the blood to the lower ventricle.

At the same time when the right ventricle is getting the blood from the veins, at the same time the left atrium they are collecting the blood coming from the lung and both these chambers upper chambers or the atrium they get compressed simultaneously and allow the flow of blood from the atrium to the corresponding ventricles. And again once actually now there are some valves which are controlling the flow so that the flow is unidirectional; after sometime this atriums they are relaxed and they stops the flow of the blood to the ventricles.

Now at that moment the ventricles they should actually get contracted and then the valves which were. So, far allowing the flow of blood from the atrium to the ventricles they actually get closed and the new set of valves they get opened, which allows the out flow of the blood from the right side of ventricle, it goes to the lung and from the left right it is going throughout the body.

Now, let us look at that how these activities are controlled, now here the ventricles also will be in compressed state for some time and then they should get relax and get ready for the next cycle because, by the time when they are actually throwing out the blood or pumping out the blood outside the that the heart, at the same time the arteries sorry atriums they are accumulating the blood from outside the right atrium that is getting blood from the vein and the left 1 that is getting from the lung. Now let us see how this actually sequence is controlled in the heart, there is some region which contains some nerve cells called they acts as a lead or lead singer they actually give the first signal and along with that there are many other nerve centers, which helps to build up the potential and as soon as they give the signal that electrical potential that slowly gets transmitted through out the valves of this atrium.

They flow through the muscles as well as that some nerves called that the Bachmann's bundle and slowly as the potential that travels through the valves of the atrium, they actually start the compression of the muscles in the this the valves of the atrium, as the atrium gets compressed the blood started their flow towards the ventricle by opening some valves. And at this moment if ventricles also start actually compression by mistake, then the blood cannot be actually push towards the ventricles because, ventricles are much stronger then the that pumping pressure of the atriums.

So, we need to make sure or the system need to make sure the ventricles should not compress at that time they should remain relaxed and in expanded state. So, for that there is a note call AV node which acts as a buffer, it get the signal which is coming from the sinus node and it arrest actually that signal just like the registered we see in that electronic circuit or the digital circuit. So, the buffer that signal and give it delay that delay for the compression of the flow of blood from the upper chamber that is the atrium to the ventricles. Once a transfer is complete then the AV node release is that signal and it gives it to that it is thick actually nerve or bundle of nerve, which called bundle of hise and this bundle of hise it branches out in 2 branches that left and the right bundle branch and they are connected with smaller nerves called purkinje fibres.

Now, because of this strong that networks of this nerves throughout this ventricle, whenever the signal comes out of the AV node that signal reaches every part of the ventricles at the same instant and all parts of it started the compression simultaneously; unlike the atrium where the compression starts at 1 point and it starts in a very slow manner. Now as soon as it start the compression the blood pressure within the ventricles that goes up, that closes the valves which where allowing the flow of the blood from the atrium to the ventricles and opens the outlet valves. The right ventricle that is pumping out the blood towards the lung and here we should keep in mind that the vessels which are taking out blood from the heart they are all called arteries.

So, the pipe which is taking the blood from the right ventricle to the lungs that is also called actually 1 artery pulmonary artery, though it is carrying actually carbon dioxide rich blood and whatever the pipes they are actually giving back the blood to the heart they are called veins. So, from the lung the blood which is oxygenated or oxygen rich that is coming back that is also again we will call as a vein, that is the important difference with rest of the network where usually we get that whatever the blood that pumps out from the left ventricle, that is distributed throughout the body through the arteries and it comes back to the vein and we pump out oxygenated blood and what we get back that is the carbon dioxide rich blood and if we actually take the that is we look at the electrical signal which controls the activity of this heart.

If we record that we see that first we get a small wave that is called the P wave, which is responsible for the contraction of the upper chamber or the atriums, then once it gets compressed and it continue to remain as that compressed state and AV node actually arise that signal. So, we get very less of electrical activity we get that isoelectric line this part that P to R interval or P to Q this distance, that time there is no prominent electrical signal.

Then again once the AV node releases that signal, we get the a huge electrical activity which is shown as a or recorded as a Q R S wave form, this is actually due to the electrical activity in the ventricle or associated with the compression of the ventricle. Once the ventricle get compressed it remains in the state for a good amount of time and we get again sometime when there is no electrical activity that is the time in between the S and the T. And then that ventricle starts relaxing or we can say that after the polarization the depolarization of that muscles should happen and the corresponding electrical signal is recorded as a T wave, which is responsible for the that the depolarization of the muscle in the ventricle.

When actually the ventricles are compressed or getting repolarized, at the same time that the cells in the muscle cells of the atrium they are getting relaxed or getting depolarized, but because they are signal is weak that we do not get the impression or we can say they are actually massed by the higher activity of the that ventricular that muscle cells and that Q R S complex. So, we could not get as a separate signal for the depolarization of the atrium and after this there is actually a gap again once the blood actually gets accumulated in the upper chambers of the atrium, again the next cycle starts with a P wave and 1 interesting thing we see that, to get the blood here accumulation it takes a good amount of time.

So, if you look at the distance between P to T, that is actually that activity is much small compared to 1 complete cycle of the ECG, in other words the active period of the heart where the that compression is taking place is much small compared to the overall cycle or time period.

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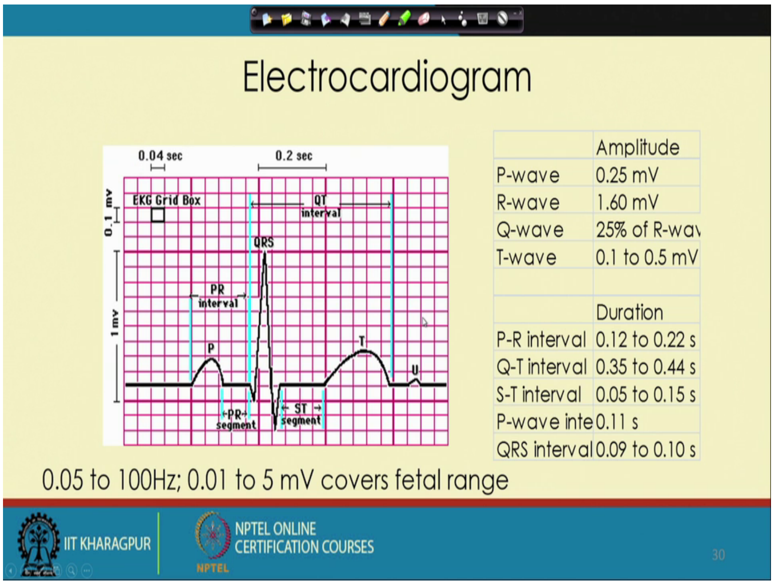

Now, let us look in more detail into the activities of the electrocardiogram. The first part we told that is P wave that is responsible for the contraction of the atrium, it has very small voltage it is about 0.25 milli volt and after the P wave, we get a small interval that is the PR segment. So, in the PR segment that we get that it is going down first a little, we get this point as the Q and the maximum voltage where you got it is called that R point then it comes down again called the S.

So, this one this R wave that is having the maximum magnitude, that is the voltage is about 1.6 milli volt and these actually change in voltage in the QRS complex is much faster compared to the P R wave form, and after that again there is a isoelectric line or no activity we can say no electrical activity that is the S T segment. And again once the muscles of the ventricles they relaxed and the depolarization happens along with that it generates and other wave which is again slowly moving just like the P wave and their voltage is also similar it is about 25 percent of the R wave or even less than that.

So, 0.1 to 0.5 mill volt. So, we get that and if we look at the overall time frame we get that P R interval from P to R that is 0.12 to 0.22 second compared to that that Q to 2 Q to T that means, that ventricular time period these time that when the compression and decompression is taking place is longer 0.35 to 0.44 within that, where that it remains in the compressed state, that is a S T segment it is 0.5 to 0.15 second. And if you look at individually the P wave when the compression is taking place in the atrium that is point

0.11 and the Q R S interval starting from here to here that is having the actually that is minimum amount of time 0.09 to 0.1 second. And that this range if you look at that we know that heart is beating about 72 that cycles per minute, and for that we have actually these beating that is 0.05 to 100 hertz that kind of thing also taking into account, the fatal range and if you look at the magnitude of the signal that is in the milli volt range 0.01 to 0.5 milli volt.

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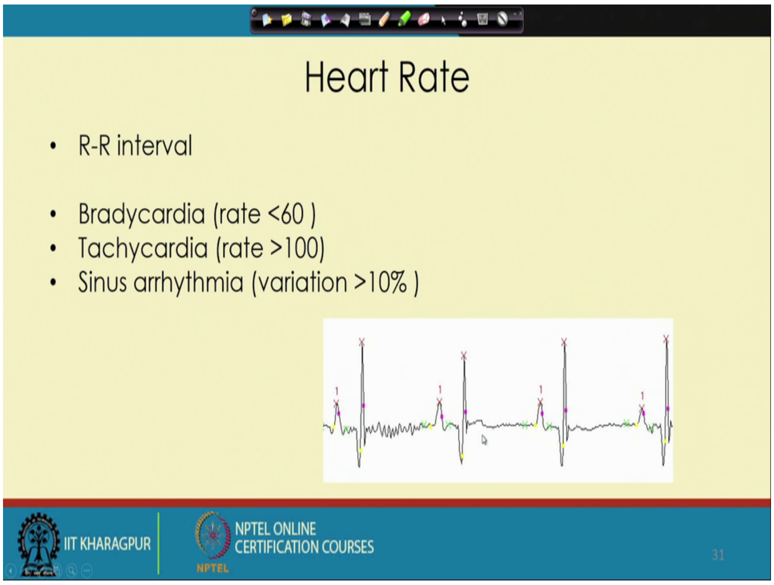

The not next important thing is the interval, that when we talk about the heart is beating it is actually marked by the 2 R points, the interval between these 2 the reason is R point is the highest peak and they are the most prominent point. So, though the cycle can be actually computed from any 2 similar points, we count it using the R R interval and if the rate is within some limit we call the heart is working in a normal wave.

However, it if it is becomes very slow if it is less than 60 per minute we call this is bradycardia, this is a state which is not desirable. What could be the problem in this case that if the heart is not pumping out at the sufficient rate, the cells in the body they may starve of oxygen and glucose. Again there could be another state when the heart is actually pumping at higher rate, say when it is above 100 beats per minute then we call that it is called tachycardia.

Now, in this case there is no problem in short supply of oxygen or glucose, but if we beat actually at higher rates, then the problem may occur with the heart; the heart muscle they give may get over worked and then after sometime they may get fatigued and stop their work completely which we can call as the failure of heart. So, that is also is a dangerous thing. So, the heart rate should not go above the 100, but in case of sports personals who have actually the capacity to work at higher efficiency, for them we can get higher actually that better efficiency of the pump and for them this rate could to be below 60 and that is normal.

And then again there is another kind of variation if within few cycles, if we see that the rate is varying that over 10 percent usually when you look at the ECG wave form, it is not exactly periodic. There is a periodicity, but there is a small variation associated with it and that is why we called as signal as a quasi periodic signal. But there is a limit within the variation, if that variation is more 10 percent then again we know that there is some problem in the system and that is called as sinus arrhythmia. So, these are primarily the problems with the heart rate which is occurring primarily, because of that how the signaling is going in the heart or how that signals are getting transmitted throughout the heart.

Thank you.