Course: Electrophysiology of Heart

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Lecture 18: Heart rate variability-interpretation& clinical uses, Blood pressure variability

Hello everyone. So, today we will start our next topic which is Heartbeat Barium Variability Interpretations and the Clinical Uses and Blood Pressure Variability. Last class we had discussed till the terminology of HRV analysis. Today we will discuss the interpretations and what is the clinical value of HRV analysis and the clinical utility of blood pressure variability. So, the interpretation as we had already discussed, first we will come to the time domain analysis. In time domain analysis 5 minutes analysis means mainly we are talking about short term HRV.

So, in this the most important parameter is SDNN that is standard deviation of NN intervals or RR intervals. So, it is the most representative parameter of HRV. It is the estimate of overall HRV and it reflects the heart intrinsic ability to respond to the hormonal influences which means it includes the sympathetic nervous system activity, parasympathetic nervous system activity as well as the circadian rhythm. Then it includes the respiration, how the respiratory influences are there in the heart rate variations, then thermo regulation as well as the neuro endocrine or the hormonal influences.

So, all the cyclical variations are usually reflected in this SDNN parameter. And also I had told you this SDNN this usually parameter is dependent on the length of the recording. The longer the recording that gives rise to the increase or higher values of SDNN. So, lower SDNN indicates low HRV obviously we have various reasons of low HRV which primarily indicates reduction in the dynamic complexity and it is associated with sudden cardiac death usually. The cardiovascular risk is very higher whenever there is a low HRV and whenever there is lower SDNN which mean that generally reflects the low HRV.

Lower SDNN means the value should be less than equal to 50 milliseconds. Generally more than we have more than 50 milliseconds to 100 milliseconds, then we have 100 milliseconds to generally 140 milliseconds moderate and high normal. So, generally less

than 50 is the cut off value for the SDNN less than 50 milliseconds we consider the person is having lower SDNN. Now, next we have the RMSSD. So, RMSSD measures the estimate of high frequency variations in the short term HRV.

And it reflects an estimate of vaguely mediated regulations or parasympathetic regulations on the heart. So, whenever there is decrease in the RMSSD which means the value is below 10 milliseconds. So, whenever there is decrease in RMSSD there has to be decrease in SDNN value also. Generally it is accompanied the decrease in RMSSD is usually accompanied with decrease in the values of SDNN. So, the lower SDNN is usually below 20 and hence there is high risk of cardiac disease development or high risk of certain cardiac death because this is low HRV again.

So, ideally the normal values ranges between 20 milliseconds to 80 milliseconds that also depending on the age and sex of the person. So, high RMSSD means it indicates the training and health recovery. The trained persons and the recovered persons the persons who are having good recovery from the diseases they have higher values of RMSSD. So, next we have NN50. NN50 measurements they also correspond to the short term HRV which are not usually related to the cyclical or the day and night changes.

And they are also usually parasympathetically or vaguely regulated. So, they reflect alterations in autonomic tone that are predominantly vaguely mediated. So, that is NN50. Now, if we are asked to like say which one is a better indicator whether it is NN50 or RMSSD. So, compared to NN50 RMSSD because both are vaguely mediated.

So, compared to NN50 RMSSD is said to be more stable and preferred. So, out of this two index RMSSD and NN50 we prefer more RMSSD values. So, next we have the frequency domain parameters. So, frequency domain parameters we are talking about the absolute parameters absolute measures that is total power that is MS 2. So, total power is a short term estimate of the total power of power spectral density which lies in the range between 0 to 0.

4 hertz. So, the frequencies is 0 to 0.4 hertz and the power is the short term estimate of the total power of power spectral density which lies in the range of the frequency 0 to 0.4 hertz. As I told you total power reflects the overall autonomic activity. It is similar to that of the SDNN of time domain measures.

So, the primary contributor is actually parasympathetic activity though it reflects overall autonomic activity, but sympathetic activity is the primary contributor. Generally, decrease in total power is observed under chronic stress or with chronic diseases like diabetes you have hypertension you have. So, low TP means the value is less than equal

to 1000 MS 2. So, low TP means the value is equal to less than equal to 1000 MS 2. Then the most important thing in the previous slide is this total power can is divided into again short term and long term.

Since, we are talking about the short term HRV 5 minutes HRV. So, in case of short term HRV 5 minutes total power usually reflects this overall sympathetic activity that is overall autonomic activity that means sympathetic activity and parasympathetic activity. But when we are talking about 24 hour or long term HRV at that time TP usually includes the neuro endocrine variations or the neuro endocrine or hormonal variations and the cyclical variations are usually included. So, this is all about your total power. Next coming to the very low frequency, the very low frequency is a band of power spectrum which lies between the frequency 0.

003 to 0.04 hertz. It again indicates overall activity of various slow mechanisms of sympathetic functions. And as I had described in the previous lecture that it is of very less importance. This very low frequency does not provide much meaning they often reflect meaningless noise signals but it is it has got role in obstructive sleep apnea. Now, what happens this VLF is increased usually we see increased VLF in obstructive sleep apnea OSA. Because in case of obstructive sleep apnea there is respiratory arrest there are episodes of respiratory arrest in hypoxemia which is related to the hypoxemia.

So, this frequencies this increased very low frequencies are usually synchronized with this episodes of respiratory arrest which is related to hypoxemia in obstructive sleep apnea. So, that is why it plays a very important role in obstructive sleep apnea. Otherwise it has got no role much low frequency MS2 LF this is a band of power spectrum which lies in between the range of 0.

15 0.04 to 0.15 hertz. This measure reflects both sympathetic and parasympathetic activity. Now, to measure first and foremost the frequency domain analysis or the power spectral analysis generally long term HRV is not measured with the help with this frequency domain analysis. Generally we go for short term HRV first and foremost. Now, whenever we are going for short term HRV measurement and we are taking the frequency domain parameters for long term HRV generally we prefer time domain analysis. So, whenever we are preferring short term HRV and the frequency domain parameters we should make sure the person is having normal breathing.

Because anyway respiration plays a very important role in the heart rate variability. So, whenever a person is if the persons breathing is controlled, controlled means if the person is having approximate less than or equal to 7 breaths or deep breathing at that time this parasympathetic domain plays a very important role and the LF value gets

deranged. So, this usually gets reflected in the low frequency values. Otherwise low frequency reflects both sympathetic as well as parasympathetic activity predominantly it reflects sympathetic activity. That means, whenever there is increased sympathetic activity LF value will get raised.

But if the parasympathetic activity is getting increased also then also your LF values will get raised because at that time the person is having deep breathing. So, parasympathetic influence is presented by LF when respiration rate is lower than 7 breaths per minute or during taking a deep breath. That is why the person should have natural breathing and it should not be controlled breathing. High frequency is a band of power where the spectrum range between 0.

15 to 0.4 hertz this is high frequency band. And this measure reflects usually vagal activity or parasympathetic activity. This is also known as respiratory band and because it corresponds to the NN variations which is caused by respirations mainly we are talking about respiratory sinus arrhythmia. So, high frequency band usually corresponds to the respiratory sinus arrhythmia and this measure is usually reflected with the vagal activity of the autonomic nervous system or the parasympathetic activity. Now, coming to the LF HF ratio this is very important because this ratio actually says about the sympatho-vagal balance in our body.

That means, what is the balance between the sympathetic nervous system and the parasympathetic nervous system. So, this is the ratio between the power of low frequency and the high frequency bands. This measure indicates overall balance between sympathetic and parasympathetic nervous system. Higher values means whenever the LF HF ratio is more this usually means the sympathetic nervous system is dominant. And lower values whenever the LF HF ratio is less it means the parasympathetic nervous system is dominant.

Usually the values the LF HF ratio not only it should be less than 2. The LF HF ratio normally it should be less than 2. It has got a range from 1.5 to 2 normally it should be less than 2. So, this LF HF ratio gets deranged particularly whenever there is an autonomic dysfunction or dysautonomia due to various diseases.

So, this is the diagram this is which shows the decompositions of various components. And you can see this is the original wave which we are getting and this has been decomposed into VLF frequency low frequency and high frequency. Because the quantifications because of the decomposition into various components the quantifications of various frequencies are done. And this is the power spectral analysis which consists of very low frequency low frequency and high frequency. And this is the

percentage power that is in normalized units.

And as I already told you normalized unit is nothing but the ratio of the absolute measure of a particular frequency to the total power. And this total power does not include or it excludes the very low frequency. So, here you have the HF here you have the LF and here you have the very low frequency normalized units which is termed in NU. So, when this powers gets reduced or abnormal reduction of total power as we had seen whenever the ANS autonomic nervous system is disturbed or decreased. The lower adaptability of the heart, heart is not able to adapt to the stressor.

There is decreased ability to cope with the requirements of the continuously changing environment. Whether it is internal stressor or external stressor my body is not able to cope my autonomic nervous system is totally dysregulated. At that time there is reduction in the total power because total power denotes the overall autonomic activity including the circadian rhythm and the neuroendocrine variations. Then when there is reduction in the very low frequency when this very low frequency as I told you very low frequency anyway this signals is much it is related to the noise signals, but it plays a very important role with respiration. So, this is related to body temperature, thermoregulations, lack of oxygen, lack of oxygen, hypoxemia as I told you obstructive sleep apnea this results this values get increased.

And 5 minute measurement does not have a significant meaning for very low frequency you need to have a longer recording. Short term recording 5 minutes anyway you would not be getting any results. When the low frequency gets reduced low frequency means I am talking about both sympathetic nervous system which is very much predominant as well as parasympathetic nervous system which is mildly predominant. So, whenever there is loss of energy, tiredness, fatigue, insufficient sleep, lethargy less. So, that at that time there is reduction in the low frequency the sympathetic domain is decreased which means this whenever the person is having anxiety this L f value will get increased.

There is reduction in the H f, H f is mainly high frequency where pre sympathetic activity is mainly dominant it is vaguely regulated. So, this is reduced whenever there is chronic stress, aging, reduced electrical stability of the heart, it can be organic functional or there can be gastrointestinal disturbances in digestion. Now, aging old age also gives rise to decrease in the autonomic nervous system. So, that gives rise to lower H r b which further gives rise to various diseases like hypertension, loss of elasticity of the blood vessels arteries. So, that is why in aging we get reduction of the higher frequency.

So, frequency domain measures in a nutshell what we get total power the area which lies under the power spectral density of 0.003 to 0.4. It gives the total variability or the total

activity of the autonomic nervous system and it is equivalent to S D N N of the time domain this S D N N is of time domain measures. And high frequency it is the frequency range from 0.

15 to 0.4 hertz this table you have to remember the parasympathetic modulation of the heart rate mainly respiratory sinus arrhythmia. Then we have the low frequency des density which lies between 0.04 to 0.15 hertz this is mainly because of the sympathetic modulation along with the contribution of parasympathetic activity sympathetic more parasympathetic activity less.

Very low frequency 0.003 to 0.04 this is mainly regulated by slow blood pressure oscillations and same H F and L F can be normalized units the mechanisms or interpretations are the same. The L F H F ratio is the autonomic or the sympatho vagal balance which is between the sympathetic and the parasympathetic activity in our body. Now, the correlation of the frequency domain and the time domain with respect to cardiac autonomic control. So, total power this I had already told you usually coincides with the S D N N of time domain. And this usually reflects the total autonomic activity that is circadian as well as sympathetic and the parasympathetic activity.

Now, this T I N N or triangular index is the geometrical analysis which is very complex and which is usually obtained from the histogram plots of all the R R intervals. And this is usually this H R B triangular index is meant for long term recording of H R B higher frequency and N N 50 R M S S D this is mainly for the parasympathetic or vagally mediated role of actions. Low frequency and S D N N as well as S D N N index we have again sympathetic and parasympathetic, sympathetic more and parasympathetic to a certain extent less as compared to sympathetic. And very low frequency that is mainly circadian or the blood pressure oscillations. So, these are the correlations of the frequency domain parameters as well as time domain parameters in relation to the cardiac autonomic control.

Which branch of autonomic nervous system whether it is sympathetic branch or parasympathetic branch is giving rise to the particular power or frequency that is been shown. Now, coming to the non-linear methods. Now, non-linear methods as I told you this are usually done for the complexities or to find out the self similarities. And the most important non-linear methods now what is it is seen in the Poincare plot analysis also known as scatter plots also known as phase delay plots. So, these are the various names which are given for the non-linear methods.

Now, it reflects the graphical correlations between consecutive R R intervals. This is this naming is usually after Henry Poincare the scientist which gave rise to this Poincare

plots. Now, what is this actually Poincare plots? All the R R intervals the R R intervals are usually plotted in two dimension. So, we can see the two dimensions one is the x axis and the other one is the y axis. In x axis and y axis they are plotted in two dimensions and we have various descriptors for this dimensions.

So, generally S d 1 is one descriptor and S d 2 is other descriptor. These are the descriptors. Now, the points of dispersion this is the point of dispersion which lies perpendicular to the line of identity. This we can see it is lining perpendicular to the line of identity.

This is S d 1 which denotes short term H R V. This is usually the short term H R V. So, S d 1 is short term H R V which is nothing but respiratory sinus arrhythmia R S A. And the point of dispersion which is lying along or lying parallel to the line of identity that is S d 2. So, S d 2 is the long term H R V. This usually denoting the neuro endocrine functional variations as well as the cyclical variations or the circadian rhythm.

So, these are the mainly this is how the Poincare plot analysis are done. As I had already told you the fractal dimensions and the chenon entropy these are usually done with the help of convoluted neural networks and support vector machines. These are the entities of artificial intelligence or machine learning which are in use now a days. So, the task force of European society of cardiology has given some normative values of this H R V. Generally we do not get to see the standardized values of the various parameters which are used in H R V.

But we follow the task force European guidelines society of cardiology guidelines. So, S d n n value these are the normal values that is 141 plus minus 39 around 141. And as I told you less than 50 is the cut off value that means lower S d n S d a n n 127 milliseconds R M S S d 27 plus minus 12 as I told you it ranges between 20 to 80 milliseconds. And S d n n less than less than equal to 50 milliseconds is the lower S d n n H R V this is the triangular index geometrical analysis 37. Then we have the spectral analysis in case of 5 minute recording total power M S 2 3466 L F lower frequency M S 2 this is 1170 H F 975 M S 2.

Here we have the normalized units of L F and H F and finally, the L F H F ratio. This I told you the L F H F ratio should be the normal value should be below 2 and 1.5 to 2 is the normal range increased in L F H F ratio means sympathetically predominant. And decrease in L F H F ratio means parasympathetically predominant. So, this is the task force of the European society of cardiology which has given some normative values of the standard measures of the H R V or heart rate variability.

So, this is the frequency domain analysis of the power spectral analysis. You can see the normalized power unit is given and this is the frequency which is lying from 0 to 0.4 hertz 0 to 0.4 hertz. So, this is the normalized power that means the percentage of the power we will see.

So, this is the very low frequency till 0.05 0.03 hertz the 0.04 hertz and then we have the low frequency band from 0.04 to 0.15 hertz.

And then we have the high frequency band that is from 0.15 to 0.4 hertz range this is the high frequency. High frequency is mainly because of the parasympathetic component low frequency is mainly because of the both parasympathetic and well as vagal component mostly by the parasympathetic dominance. Now, coming to the heart rate variability in various diseases. What are the diseases we see and what are the challenges and what are the clinical values utility of heart rate variability in this diseases.

Now, first we will see the cardiovascular entity. Heart rate variability is a very important indicator in case of early diagnosis of autonomic dysfunctions in case of myocardial infarction and also post myocardial infarction. It usually calculates the mortality risk of in case of the patients who are post myocardial infarction or post stroke. Then we have angina pectoris then we have ventricular arrhythmias various arrhythmias we are already discussed sudden cardiac risk death coronary artery disease then we have congestive heart failure. Then autonomic neuropathy we have diabetes mellitus diabetic autonomic neuropathy brain injury epilepsy obesity multiple sclerosis gillian bari syndrome. Then diseases which are solely associated with autonomic dysrhythmias that is depressions fibromyalgia various sleep disorders asthma dizziness dizziness here means actually of orthostatic hypotensions syncope we talk about irritable bowel syndrome panic disorder chemical sensitivity chronic fatigue syndrome migraine hypoglycemia hypertension premenstrual syndrome and anxiety the psychiatric disorders we have depression anxiety and chronic fatigue syndrome and sleep disorders also we have.

So, these are all the diseases what we can see and various work have already been done in finding that various research there is extensive literature available in the PubMed database as corpus database and base database also you can see that various literature available based on the autonomic dysfunctions related to this diseases not only cardiac diseases psychiatric diseases neurological disorders also now a days we see it in parkinsonism now a days autonomic dysfunction is also been reported in patients who are having parkinsonism. Now, heart rate variability and various applications hence we get differential index the motility risk post myocardial infarction the in case of diabetes mellitus cardiovascular motility drug therapy we want to give various drugs the effect of thrombolysis on HRV after the drugs thrombolytic drugs are given the effect of

thrombolysis on HRV and then after the drugs anti thrombolytic drugs are given what is the effect of HRV then bio feedback and exercise training in case of athletes and sports medicine this is an upcoming field of research that exercise training and the role of heart rate variability in it to assess the cardiovascular health in the athletes. Now coming to the last entity that is blood pressure variability blood pressure now since heart rate is variable blood pressure is also variable this blood pressure variation is again seen based on individual to individual there is variation based on the age of the time of the recording whether you are recording it in the morning in the day in the night then there is a dynamic and in which posture variations are there. So, this represents a dynamic and characteristics physiologic feature of cardiovascular system function which is widely been different and among individuals subjects in response to their daily challenges and also determined by characteristic reactivity of their cardiovascular control mechanisms already in blood pressure we had discussed the short term regulation of blood pressure and long term regulation of blood pressure. So, why there is regulation of blood pressure because as the our autonomic nervous system or our body is shown to challenges along with the heart rate the blood pressure will also get changed it will not remain constant.

So, there has to be some regulation of this blood pressure short term as well as long term. So, that the perfusion remains unaltered or unchanged or undisturbed. So, there was a study where the there is blood pressure variability between two individuals also over time. So, you can see this is the systolic blood pressure and this is the diastolic blood pressure there is variation in the systolic blood pressure and there is variation in the diastolic blood pressure between two individuals. So, this is lower blood pressure variability and this is higher blood pressure variability.

As I told you in heart rate variability the increased or higher heart rate variability or increased HRV is actually good for health that is good for cardiac function, but it is just the reverse the increased or raised blood pressure variability is not good for health your blood pressure is extremely variable means it is fluctuating a lot and ideally it should not fluctuate that much the blood pressure should not fluctuate that much. So, the patient with higher blood pressure variability has got more cardiovascular risk. So, blood pressure variability subtypes can be short term and long term the mechanisms solely depends on the short term regulation of the blood pressure and the long term regulation of the blood pressure. That means, the baroreflex mechanism the cardiopulmono reflex mechanisms and the CNS ischemic response in case of short term regulation of blood pressure. Then we have the long term regulation of blood pressure that is the capillary shift mechanisms and the RAS or the renin angiotensin aldosterone mechanism.

So, short term blood pressure variability means within 24 hours very short beat to beat blood pressure recording variation is there within 24 hours minute to minute hour to hour

day to day within the day the blood pressure variations is there that is short and very short is beat to beat variations the same we get in heart rate variability. Long term blood pressure variability is day to day visit to visit and seasonal variations can be there. So, how do we assess this blood pressure variability we have same indices as that we had in heart rate variability also. So, indices are standard deviation coefficient of variations day to night blood pressure shifts or changes average real variability and residual blood pressure variability. For continuous beat to beat recording generally we go for standard deviation for office blood pressure monitoring we go for standard deviation coefficient of variation and average real variability.

So, S D is standard deviation C V is coefficient of variation and A R V is average real variability. For 24 hour ambulatory blood pressure monitoring again we go for standard deviation coefficient of variation then home based blood pressure monitoring standard deviation coefficient of variation and the same we go for the visit to visit blood pressure recording. So, these are the various types of blood pressure variability and which is given in the form of chart. The continuous BP recording is done for beat to beat very short ambulatory blood pressure monitor is for within 24 hours day to day if it is more than 48 hours ambulatory blood pressure monitoring home based and ambulatory both for long term that is visit to visit. The advantages is indices of the autonomic modulation we get to see in beat to beat very short means the baroreflex mechanisms are only mainly detected.

Circadian variation is within 24 hours whether there is a dip in the morning whether there is a dip in the night for long term monitoring mainly we go for the long term blood pressure variability. The spectral analysis and the standard deviation are the indices we get for the beat to beat blood pressure variations. Now, what is we get non-invasive beat to beat blood pressure monitor which actually rule or which actually illustrate the standard deviations and this indices spectral analysis. Then we have 24 hour day and night time standard deviations coefficient of variations for 24 hour then standard deviation and coefficient of variation for the long term. The mechanisms are more or less same to that of the short term regulation and the long term regulations there is increased central sympathetic tone reduced cardiopulmonary or arterial baroreflex ventilations and behavioral factors for beat to beat variations for short term variations also the same.

For long term variations generally there is reduced arterial compliance and there is non compliance either to the either there is a non compliance to the anti hypertensive treatment or there is irregular or improper anti hypertensive treatment going on. So, that is why there is a long term blood pressure variability. So, the circadian variability of blood pressure is also present like beat to beat variability there is a morning surge in blood pressure or there is a night dip in the blood pressure that is the circadian variability

of blood pressure. In the study we could see there is a 24 hour mean arterial blood pressure and this is a 24 hour mean systolic blood pressure. This is the study shown which is correlating the 24 hour blood pressure variability with the target organ damage in hypertension.

Generally in hypertension in the late phase the usually there is a target organ damage or multi organ failure occurs. So, how this 24 hour blood pressure variability is correlated we would see in the mean arterial pressure standard deviation this is target organ damage severity this is systolic blood pressure 24 hour standard deviation and this is carotid artery intima media thickness. So, we can see this p value is quite significant in case of target organ damage severity when it is compared with the 24 hour blood pressure variability which means the more variability is there the more chances of target organ damage is present in case of hypertensive patients. Same there is a risk of high risk of stroke in cases of patients who are having morning BP surge in this Oha Sama study has shown whenever the person is having whoever persons are having morning BP surge they have to be very careful and they have to take very precautiously the anti hypertensive medications and to prevent from certain cardiovascular risk or certain cardiac death.

So, higher 24 hour blood pressure variability that means higher cardiovascular risk. So, increased like increased or raised blood pressure variability not good for health, but increased HRV is definitely good this is the crux of the story. So, short or long term blood pressure variability generally we go for short then short term HRV is 5 minutes long term HRV is 24 hour HRV is again age dependent sex dependent it has got circadian rhythm and chronic low HRV means there has to be some systemic health issues which is delineating or deviating your dysregulating your autonomic nervous system. So, these are the references. Thank you.