THE ASSOCIATION BETWEEN HEART RATE VARIABILITY AND HEART RATE TURBULENCE: A LITERATURE REVIEW

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ABSTRACT: In many countries, heart disease ranks among the leading causes of death. Thus, having reliable tools for assessing a patient's heart health is essential. The analysis of heart rate variability (HRV) and heart rate turbulence (HRT) can facilitate a preclinical diagnosis that may help reduce morbidity and mortality rates. Patients with chronic heart failure (CHF) experience a notably high mortality rate, which can be estimated through HRV. This estimation can be further refined by exploring the relationship between HRV and HRT parameters. Therefore, this research reviews the association between HRV and HRT parameters across various disorders of the autonomic nervous system.

Index terms: Heart rate variability, Heart rate turbulence, Autonomic Nervous System, Heart Rate.

I.INTRODUCTION

In most countries of the world, the major cause of death is heart disease [1]. It is also a significant contributor to disability. There are numerous types of cardiac disease. The constriction or blockage of the coronary arteries, the blood channels that supply blood to the heart, is the most common form of heart disease. This is known as coronary artery disease, and it develops gradually over time. It is the leading cause of heart attacks [2]. Other types of cardiac abnormalities can occur, such as problems with the heart's valves or a heart that does not pump effectively, resulting in heart failure. Heart rate variability (HRV) and heart rate turbulence (HRT) are used to assess changes in cardiac autonomic functioning as well as to stratify risk in both cardiac and non-cardiac illnesses.

The heart rate of a person is calculated by counting the heartbeats within a minute. The variation between successive heartbeats is known as heart rate variability (HRV). Heart-brain interactions and dynamic non-linear activity of the autonomic nervous system (ANS) produce HRV, which assesses neurocardiac function [3]. HRV is an emergent property of a complex regulatory system operating on multiple time scales to help individuals adapt to environmental and psychological challenges. It is measured in three ways: time-domain, frequency-domain, and non-linear methods [4]. HRV time-domain indices measure the variability in the interbeat interval (IBI), the time between successive heartbeats. These values can be expressed in original units or as their natural logarithm (ln) to achieve a more normal distribution. Frequency-domain measurements estimate the distribution of absolute or relative power across four frequency bands. Heart rate variations have been categorized into ultra-low-frequency (ULF), very-low-frequency (VLF), low-frequency (LF), and high-frequency (HF) bands by a task group of the European Society of Cardiology. The power within a frequency band represents the signal energy. The ULF band (≤0.003Hz) reflects IBI fluctuations over periods from 5 minutes to 24 hours, calculated using 24-hour data. Rhythms with periods from 25 to 300 seconds fall into the VLF frequency range (0.0033-0.04Hz). Respiratory rates of 3 to 9 bpm influence the LF band (0.04-0.15Hz), which encompasses beat intervals from 7 to 25 seconds. In a 5-minute sample, there are typically 12 to 45 episodes of fluctuations. Breathing rates of 9 to 24 bpm affect the HF band (0.15-0.40Hz). Under controlled conditions, the ratio of LF to HF power can be used to determine the balance between sympathetic and parasympathetic nervous system activity. The total power over a 24-hour cycle is the sum of the power in all the VLF, ULF, LF, and HF bands. HRV time-domain parameters include SDNN (standard deviation of NN intervals), SDANN (standard deviation of the average NN intervals for each 5-minute segment within a 24h HRV recording), pNN50 (percentage of successive RR intervals differing by more than 50 ms), and RMSSD (the root mean square of successive RR interval differences). Nonlinear measurements help quantify the unpredictability of a time series.

The term HRT refers to short-term changes in the length of a sinus cycle that occur as a result of spontaneous ventricular premature complexes (VPCs). When compared to the pre-VPC rate, the sinus rate decelerates at first and then returns to baseline in normal people [2].

As shown in Figure 1, turbulence onset (TO) and turbulence slope (TS) are two metrics used to quantify two phases of HRT: early sinus rate acceleration and late deceleration. Turbulence onset is calculated using equation 1 given below:

$$\mathrm{TO} = \frac{(\mathrm{RR}_1+\mathrm{RR}_2)-(\mathrm{RR}_2+\mathrm{RR}_{-1})}{(\mathrm{RR}_2+\mathrm{RR}_1)} \times 100[\%] \quad (1)$$

Where RR_2 and RR_{-1} are the 2 R-R intervals immediately preceding the VPC coupling interval and RR_1 and RR_2 are 2 R-R intervals immediately following the compensatory pause.

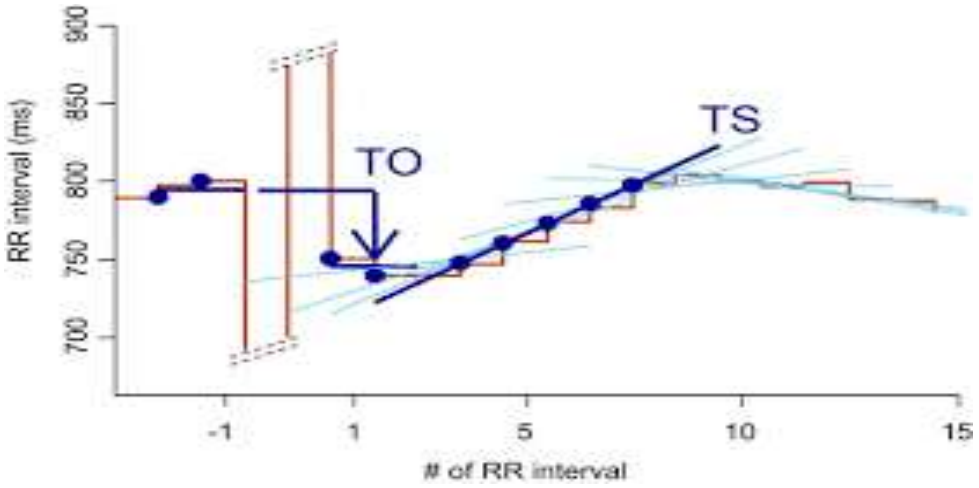

Fig.1: HRT calculation [2]

Turbulence slope is defined as the maximum positive regression slope calculated over any 5 consecutive sinus rhythm R-R intervals within the first 15 sinus rhythm R-R intervals after the VPC. The TO and TS variables can be used as clinical variables independently or in combination. HRT values are commonly divided into three groups in risk stratification studies:

1. TO and TS are normal in HRT category 0 patients.
2. HRT category 1 indicates that one of the TO or TS hormones is abnormal.
3. Both TO and TS are abnormal in HRT category 2.

HRT is classed as HRT category 0 if HRT cannot be estimated because no or too few appropriate VPC techograms are identified in recording patients who are otherwise in sinus rhythm.

II.ASSOCIATION BETWEEN HRV AND HRT FOR VARIOUS HEART DISEASES

The authors in [3] presented a study to investigate a relationship in those with coronary artery disease, between heart rate turbulence, heart rate variability, and the number of ventricular premature beats (VPBs). A 24-hour ECG holter monitoring was used to calculate mean, heart rate, number of VPBs, time-and frequency-domain HRV parameters, and two HRT parameters: TO and TS. The results of the study revealed that TS has a strong relationship with heart rate. Lower heart rate is connected with greater TS levels, while higher heart rate is associated with lower TS values. There was a significant correlation between TS and mean RR interval, but none between TO and RR interval. Patients with fewer than 10 VPBs/24 hours had significantly higher TS levels than those with more frequent VPBs. HRT and HRV parameters were found to have a significant relationship, with TS having a greater link with HRV parameters than TO. The influence of heart rate on turbulence slope suggests that this parameter should be adjusted for heart rate.

In 2007,[5] published a study on the link between HRV and HRT in children. A total of 410 youngsters (200 males and 210 girls) ages 1 month to 19 years were enrolled in the study. The patients were divided into groups to see how age and pubertal state affected HRT parameters viz. (A) up to 1 year, (B) from 13 months to the start of puberty, and (C) postpubertal age up to the 19th year of life. Then HRV and HRT analysis was performed. The average RR interval was 0.432s to 1.230s. HRV parameters had substantial differences in value between groups. For TO, HRT parameters ranged from -28.4% to 7%, while for TS, they ranged from 0.47 to 23.5 ms/RR. The majority of HRV measures in study group A had favourable associations with TO and TS. Only three of the study group B variables (SDNN index, RMSSD, and HRT 1) showed a significant connection with TO. In study group C, no such dependencies were discovered.

In [6], a study compared the connection between HRV and HRT in patients with type 2 diabetes mellitus with those without cardiac autonomic neuropathy (CAN). CAN is a very complex and complicated consequence of diabetes mellitus (DM) that puts one's heart at danger. The goal of this study was to find out how HR variability and HR turbulence can be used to detect CAN in patients with type 2 diabetes and no evident heart disease.

The researchers looked at 75-year-old patients who had been diagnosed with type 2 diabetes for at least two years. 90 participants were enrolled in the study out of a total of 124 who were monitored for cardiovascular autonomic function between February 2004 and October 2005. The remaining 34 were excluded since their 24-hour holter recordings did not show any ventricular premature beats, making HRT impossible to assess. Statistical and geometrical methods were used to examine time-domain HR variability measures. When TO was < 0 percent and TS was > 2.5 ms/RR interval, the HR turbulence score was 2, 1 if any one of above two conditions was satisfied, and 0 when none of them was satisfied.

The cardiovascular reflex tests identified 35 patients as CAN+. The CAN- group consisted of the remaining 55 patients. In terms of the link with DM duration, the TS was determined to have the most power out of all the HRV and HRT characteristics. The triangle index was the most strongly associated parameter among HR variability indices.

In individuals with mitral valve prolapse (MVP) and non-significant regurgitation, [7] presented findings on the association between HRV, HRT, and the number of ventricular premature beats. MVP is a valvular heart condition that is almost invariably linked to cardiac arrhythmias. The patients were chosen because they had MVP and mild regurgitation as indicated by transthoracic

echocardiography, as well as ventricular arrhythmia as confirmed by holter ECG. Those with diabetes, thyroid issues, liver or kidney disease, or any type of cardiovascular disease, such as coronary artery disease, were also ruled out, as were those taking heart-rate-altering drugs. There were 68 participants in this study (31 males and 37 women) who were either sick or asymptomatic.

The age and gender of the turbulence onset normal and abnormal groups were kept matching to each other in the analysis. Although there was no discernible variation between the two groups, those with a TO of less than zero had a higher TS value. The normal group had a somewhat greater VPC frequency when compared to the number of VPCs. However, there was no meaningful link between the two groups.

There was no important correlation between HRT and HRV and TO value when HRT and HRV were compared. When comparing the TS value to the majority of HRV values, however, significant connections were discovered. The results also revealed that in TS, the time domain had greater correlations than the frequency domain.

In 2008, [8] reported for patients with atrial synchronous ventricular pacing. A total of 24 instances were evaluated in this investigation. The study included 12 healthy control patients and 12 patients with high-degree atrioventricular block who were implanted with a permanent VDD pacing system for high-degree atrioventricular block. According to the European Society of Cardiology, the HRV study was performed to compute features in time domain and frequency domain during a 24-hour period.

The original Schmidt method was used to compute HRT parameters. HRV and HRT analysis were not performed on patients with atrial fibrillation (aFib), not having PVCs, or PVCs preceded by interference or artefacts. 120 milliseconds was considered the nominal atrioventricular interval.

The average and sense wave were both 3.9 0.96 mV. The incidence of ventricular pacing was 99.80.96%. When HRT values were evaluated, the paced group had considerably higher TO than the control group, but there were no statistically significant variations in TS between the two groups. The paced group had a considerably larger number of individuals with aberrant HRT onset than the controls. However, there was no significant difference in the number of patients with aberrant HRT slope between the two groups.

Autonomic function is negatively impacted by atrial synchronous pacing. HRV values did not differ between controls and VDD patients, while turbulence onset was substantially earlier in VDD patients.

HRT and HRV parameters were measured in patients with chronic obstructive pulmonary disease (COPD) in 2009 [9]. COPD patients' cardiovascular autonomic functions are greatly influenced by respiratory system's functional and structural variations. Determining ANS (autonomic nervous system) balance could be helpful in analysing the pathogenesis of COPD and in treating COPD patients clinically. HRV and HRT are valuable techniques for evaluating autonomic functions. The aim of this study was to look at HRV and HRT in COPD patients. The study comprised twenty-five COPD patients with mild to serious symptoms and twenty-five healthy volunteers.

A 24-hour ECG holter signal was used to analyse HRV and HRT. Pulmonary functions tests and echocardiographic examinations were performed, as well as arterial blood gas analysis.

When comparing HRV and HRT parameters, COPD patients exhibited considerably lower pNN50 total, pNN50, SDANN, SDNN,SDDNI in HRV parameters, and their HRT onset features were much less negative. Although COPD patients had lower HRT slope values, there was no meaningful deviation between the two groups.

Patients with psoriasis were observed to find out relationships between HRV and HRT in 2010 [10]. Psoriasis vulgaris (PV) is a chronic inflammatory skin disease that is associated with a higher incidence of a variety of systemic abnormalities. The goal of this study was to see how psoriasis affected cardiac autonomic function by using the HRT and HRV parameters as potential indications of an increased risk of ventricular arrhythmias and sudden cardiac death.

The study included 20 psoriatic patients without cardiovascular disease and 20 healthy volunteers who were age and sex matched. A 24-hour holter recording was used to measure HRV and turbulence analysis.

In terms of clinical demographic and biochemical variables, there were no statistically significant differences between the two groups. The turbulence onset and slope in psoriatic patients were not statistically different from the control group when HRT parameters were examined. Except for the high frequency power,the HRV parameters were nearly identical.

In terms of HRT and HRV values, psoriasis did not appear to be associated with altered autonomic function.

In 2011, HRV and HRT parameters were assessed in hypothyroidism patients before and after their treatment [10]. The study included 40 hypothyroid patients and 31 healthy controls. The target of the study was to analyse cardiac autonomic function in hypothyroid patients utilising HRV and HRT measurements before and after L-thyroxine treatment. Volunteers with either subclinical or overt hypothyroidism made up the patient group. The parameters of HRV and HRT were investigated. The sick group had lower HRV characteristics than the control group, although the difference in the RR interval remained negligible. Unfortunately, no such difference could be found in the patient group before and after L-thyroxine treatment.

Turbulence onset was substantially higher in hypothyroid patients, but TS was significantly lower. There was no significant change in TO after 6 months of therapy, however there was a slight increase in TS. TSH had a negative relationship with SDNN and TS and a favourable relationship with TO.

The measurement of HRV and HRT to determine true coronary artery in patients with ST segment depression without angina during stress testing was carried out in [11] in 2011. The gold standard method for diagnosing coronary artery disease is still coronary angiography (CAD). The goal of this study was to see which HRV and HRT levels could tell the difference between real coronary artery disease and false positive stress test findings.

The study involved 90 non-diabetic patients with suspected coronary artery disease who had ST segment depression without angina during an exercise stress test and were scheduled for diagnostic coronary angiography. During an exercise stress test, only participants with ST segment depression without angina were included in the study.

The time and frequency domain parameters of HRV were obtained after a 24-hour recording was analysed. A computer programme determined the HRT parameters, TO, and TS automatically.

According to the severity of their coronary problems, patients were categorised into three groups: normal, non-obstructive, and obstructive. Only the use of acetylsalicyclic acid, which was much higher in group 3 than in group 1, showed significant differences when compared to groups 1 and 2. The significance of the P value did not change when data from groups 1 and 2 were pooled and compared with data from group 3.

The three groups differed significantly on the majority of temporal and frequency domain HRV measures. In comparison to group 1, SDNN was much lower in groups 2 and 3. In comparison to group 1, LF was reduced in groups 2 and 3. Group 3 had lower RMSSD, total power, and HF than groups 1 and 2. Group 3 had a much greater TO and a significantly lower TS than groups 1 and 2. Group 2 had a higher TO than group 1.

Similar to above research publications, there are some recent findings as well published in 2018 [12] and 2020 [13] highlighting the important relationship between HRT and HRV for assessing blood pressure control and ANS in hypertensive patients and ANS in acute ischemic stroke patients respectively. Once again the link between different parameters of HRV and HRT have been verified in these studies also. Therefore, it can be stated that there exist an important correlation between HRV and HRT features when analysed for a particular disease. This correlation, if verified properly, proves very much useful in screening of the patients non-invasively at an early stage of the disease.

III.CONCLUSION

In this manuscript, many studies have been discussed to verify the relationship between HRV and HRT parameters for different diseases. From above discussion, it can be concluded that different diseases possess different correlation between HRV and HRT parameters. Therefore, by finding appropriate correlation for a particular disease can help in treating the disease easily and at accurate time. In future, the authors of this paper would like to find out the correlation between these measures among the chronic heart failure patients and control groups.

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