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Original Paper

Analysis of the Prognostic Impact of Heart Rate Deceleration Capacity on Type 2 Diabetes Mellitus with Ventricular Premature Contractions

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Abstract

At present, one of the greatest life-threatening risks for patients with type 2 diabetes is cardiovascular complications. According to relevant research, approximately 70% to 80% of these patients die due to cardiovascular disease. Compared to non-diabetic individuals, diabetic patients face a two- to four-fold higher risk of developing cardiovascular and cerebrovascular diseases, with vascular complications resulting in an average life expectancy reduction of about 12 years. Increasing evidence indicates that cardiovascular-related indicators become abnormal as early as the initial stages of type 2 diabetes. During this period, the likelihood of adverse cardiovascular events rises, and cardiac autonomic dysfunction (CAD) begins, disrupting the balance between the parasympathetic and sympathetic nervous systems and thereby increasing cardiovascular disease risk. Cardiac autonomic dysfunction is one of many severe complications, and ventricular premature contractions are common arrhythmias in patients with type 2 diabetes, often seen as key indicators of declining cardiac function. Continuous heart rate deceleration, observed as deceleration runs (DRs) in Holter ECGs, manifests as a gradual prolongation of consecutive RR intervals, an indicator useful in assessing cardiac autonomic neuropathy. Persistent hyperglycemia or pre-diabetic states are associated with coronary artery disease (CAD), and strict blood glucose control helps slow the progression of microvascular complications. HRV monitoring is an effective method for evaluating early-stage cardiovascular autonomic neuropathy (CAN), providing a quantitative assessment of autonomic function and aiding in diagnosing other vascular complications.

Keywords

Type 2 Diabetes, Deceleration runs, Ventricular Premature Beats, Prognosis

1. Introduction

Type 2 diabetes, a chronic metabolic disorder, poses a serious threat to human health. As social and economic development progresses and living standards improve, the environment has undergone significant changes, contributing to the rising prevalence of type 2 diabetes, exacerbated by an aging population. If blood glucose levels remain elevated for prolonged periods, it can disrupt the body's metabolism of carbohydrates, lipids, and proteins, potentially damaging key organs such as the heart, brain, and kidneys, thereby posing a severe threat to life. One of the most serious complications is damage to the heart’s autonomic nervous system, while ventricular premature contractions are a relatively frequent arrhythmia observed among type 2 diabetic patients. Instability of the body's homeostasis is one of the key factors leading to cardiovascular accidents and sudden cardiac death. The balance of the autonomic nervous system is crucial in maintaining the body's internal environment. Clinically, ventricular premature contraction is often regarded as a key indicator of potential heart function impairment. The Dynamic Heart Rate Slowdown Index (DRs), which shows the progressive lengthening of the RR intervals in the dynamic electrocardiogram for each heartbeat, can reveal the presence of cardiac autonomic neuropathy (Han & Yang, 2021). This study aims to investigate the frequency of ventricular premature contractions in different areas and the dynamic heart rate slowdown index in type 2 diabetic patients. The study results will be summarized in the following report (Wang, 2021).

2. Materials and Methods

2.1 Clinical Data

This study selected 80 type 2 diabetes patients treated at our medical institution between January 2021 and December 2023, who were identified with ventricular premature beats through dynamic electrocardiography, as the observation group. Additionally, 86 healthy elderly individuals who also exhibited ventricular premature beats during dynamic electrocardiography were selected as the control group. Among the control group, 40 were female, and 46 were male, with an age range of 50 to 85 years (mean age: 68.27 ± 4.13 years). In the observation group, 32 were female, and 48 were male, with disease durations ranging from 5 to 20 years (mean duration: 9.66 ± 2.10 years) and ages ranging from 50 to 90 years (mean age: 68.29 ± 4.15 years). The body mass index (BMI) ranged from 19 to 30 kg/m^2, with a mean BMI of 23.31 ± 1.88 kg/m^2. A comparison of gender and age between the two groups showed no statistically significant differences ($P > 0.05$), allowing for a comparative analysis in the subsequent stages of the study. The hospital's internal ethics review board thoroughly examined and approved the study's compliance. Patients with various types of cardiomyopathies, congenital heart disease, hypertension, cerebrovascular disease, severe liver, kidney, or neurological damage, respiratory system diseases, or rheumatic immune diseases were excluded. The case selection in the observation group followed the diagnostic criteria outlined in the “Chinese Guidelines for the Prevention and Treatment of Type 2 Diabetes (2013 Edition).” Inclusion criteria included patients without a history of cardiac surgery, complete clinical records, and no use of medications affecting autonomic function (e.g., diuretics) in the past week (Gao, Zhang, Li, et al., 2021). Patients with myocardial infarction, heart failure, cardiovascular medication use within two weeks before the study, poor compliance, or unstable mental states were excluded from the study (Wang & Zou, 2023).

2.2 Methods

In this study, all subjects underwent testing with the dynamic electrocardiogram analysis system produced by Beijing DMS Medical Equipment Co., Ltd. (model DMS300-4AL). Their 24-hour electrocardiogram (ECG) data were recorded in detail and reviewed multiple times. All data were thoroughly analyzed by experienced clinicians. The origin of the ventricular premature beats was categorized based on the characteristics of the wide and abnormal QRS waves observed in the twelve-lead surface ECG.

2.3 Observation Indicators

1. ECG Analysis: Pre- and post-treatment ECG data were collected. This included analyzing ventricular and atrial conduction abnormalities, atrial fibrillation, ST-T segment changes, and sinus tachycardia.2 (Su, 2021). Ventricular Premature Contraction Frequency: The occurrence of ventricular premature contractions in different ventricular regions was recorded and compared before and after treatment in the observation group. The specific regions included the right ventricular outflow tract, right ventricular apex, left ventricular outflow tract, and left ventricular apex. The criteria for classifying the location of ventricular premature contractions are as follows: Right Ventricular Outflow Tract: RS or QS waveforms in lead V1, RS transition in leads V3/V4, and upward deflection of the main wave in leads II, III, and aVF.Right Ventricular Apex: The main QRS wave direction is downward in leads V1 to V4, and similarly downward in leads II, III, and aVF.Left Ventricular Outflow Tract: Lead V1 may present qR, R, rsR, rsr, or Rs waveforms. If an RS or transitional RS waveform appears in lead V2, the R wave must account for 50% or more of the QRS complex, and the amplitude ratio of the R and S waves should be 30% or more. In leads II, III, and aVF, the main wave is prominent and upward. Left Ventricular Apex: The main QRS wave direction is downward in leads V4 to V6, and similarly downward in leads II, III, and aVF.3. DRs Characteristics: A comparison of the DRs characteristics for ventricular premature contractions in different regions before and after treatment in the observation group (Ma & Jin, 2020).

2.4 Statistical Methods

In data analysis, quantitative data were evaluated using a t-test ($x \pm s$), while qualitative data were analyzed using the χ^2 test, presented as n%. For comparisons between multiple groups, the Z-test method was applied. All data were processed using SPSS 20.0 software. A P-value of less than 0.05 indicated significant differences between data groups, which were considered statistically meaningful (Xu, 2023).

3. Results

3.1 ECG Results in the Observation and Control Groups

From the analysis of the data in Table 1, we found that compared to the observation group, the incidence rates of atrioventricular conduction block, atrial fibrillation, ST-T segment abnormalities, and sinus tachycardia in the control group were significantly lower.

Table 1. ECG Results in Observation and Control Groups (n, %)

Group	Cases	Atrioventricular Conduction Block	Atrial Fibrillation	ST-T Segment Changes	Sinus Tachycardia
Control Group	80	15 (18.75%)	7(8.75%)	9 (11.25%)	19 (23.75%)
Observation Group Before Treatment	86	24 (27.9%)	20 (23.25%)	19 (22.09%)	22 (25.58%)
Z	—	2.000	2.000	2.000	2.000
P	—	0.003	0.002	0.000	0.000

3.2 Incidence of Ventricular Premature Beats Before and After Treatment in the Observation Group

From the analysis of the data in Table 2, we found that after treatment, the incidence rates of ventricular premature contractions in the right ventricular apex, right ventricular outflow tract, left ventricular apex, and left ventricular outflow tract significantly decreased. These changes were statistically significant ($P < 0.05$).

Table 2. Incidence of Ventricular Premature Beats Before and After Treatment in the Observation Group (n, %)

Time	Cases	Right Ventricular Apex	Right Ventricular Outflow Tract	Left Ventricular Apex	Left Ventricular Outflow Tract
Observation Group Before Treatment	80	19(23.75%)	23 (28.75%)	18 (22.5%)	20 (25.00%)
Observation Group After Treatment	80	10 (12.50%)	13 (16.25%)	6 (7.50%)	7 (8.75%)
χ^2	—	5.114	5.636	4.998	12.146
P	—	0.024	0.018	0.025	0.000

3.3 Compare the Probability of Complications in Patients Receiving Treatment

The complication probability of patients receiving treatment in the observation group was lower than that in the control group, and the difference was statistically significant ($p<0.05$), as shown in Table 3.

Table 3. Comparison of Complication Probabilities (n, %) among Patients Treated

Group	Cases	urocystitis	diabetic ketoacidosis	diabetic retinopathy	Probability of complication
Control Group	86	0	0	0	0(0.00%)
Observation Group	80	2	3	2	7(8.75%)
χ2					7.5278
P					0.0060

3.4 DRs Characteristics of Premature Ventricular Contractions in Different Parts of Patients in the Observation Group Before and After Treatment

In the data analysis comparing Table 4 with Table 5, we can observe that the abnormal rate of continuous heart rate deceleration capacity in the left ventricular outflow tract of the observation group was always significantly higher than the corresponding rate of the right ventricular outflow tract and the ratio of the right ventricular apex to the left ventricular apex during the monitoring period before and after treatment. This result is statistically significant ($P < 0.05$).

Table 4. DRs Characteristics of Ventricular Premature Beats in Different Locations Before Treatment in the Observation Group [n, %]

Location	Cases	Abnormal DRs
Right Ventricular Apex	20	4(20.00)
Right Ventricular Outflow Tract	44	8(18.18)
Left Ventricular Apex	17	4(23.53)
Left Ventricular Outflow Tract	22	7(31.82)
χ^2	—	3.000
P	—	0.016

Table 5. Characteristics of DRs in Different Locations of Ventricular Premature Contractions in the Observation Group After Treatment [n (%)]

Location of Premature Contractions	Cases	Abnormal DRs [n (%)]
Right Ventricular Apex	14	2(14.29)
Right Ventricular Outflow Tract	36	5(13.89)
Left Ventricular Apex	14	3(21.43)
Left Ventricular Outflow Tract	18	5(27.78)
χ2		3.000
P		0.033

4. Discussion

With societal progress and improved living standards, the incidence of type 2 diabetes is rising annually. This condition, characterized by persistent hyperglycemia, is a chronic metabolic disorder (Wang, 2020). If it worsens, it may damage multiple organs or indirectly impact overall health through vascular damage, leading to various complications (Su, 2021). Diabetes can harm the heart through three pathways, inducing multiple cardiac complications: First, diabetes accelerates atherosclerosis, resulting in macrovascular complications that primarily affect the cardiovascular, cerebrovascular, and peripheral arteries, possibly causing coronary heart disease, myocardial infarction, stroke, and diabetic foot. Secondly, diabetes affects capillaries and arterioles, disrupting microvascular structures and leading to capillary basement membrane thickening and endothelial cell proliferation, which may trigger microvascular complications, resulting in myocardial metabolic abnormalities and extensive myocardial ischemia, ultimately leading to diabetic cardiomyopathy. Lastly, diabetes may damage the autonomic nervous system, impacting both the vagus and sympathetic nerves, leading to cardiac autonomic dysfunction, manifesting as silent myocardial infarction, severe arrhythmia, and heart failure. High blood glucose levels may harm nerve cells by increasing oxidative stress, disrupting vascular endothelial function, and promoting advanced glycation end products, which gradually lead to autonomic dysfunction and potential coronary artery disease. Autonomic dysfunction may, in turn, reduce insulin secretion, impair glucose uptake by skeletal muscles, increase hepatic glucose production, and exacerbate insulin resistance, creating a vicious cycle between hyperglycemia and coronary artery disease. Among these complications, ventricular premature contractions (VPCs) are a severe arrhythmia often caused by significant vagal nerve damage, which is a major factor in sudden cardiac death (Ma & Jin, 2020). The data from this study indicate that the rate of ECG abnormalities in the control group was lower than in the observation group, both before and after treatment. In the observation group, post-treatment levels of various abnormal indicators were significantly lower than pre-treatment, with a notable reduction in VPC incidence in the right ventricular apex, right ventricular outflow tract, left ventricular apex, and left ventricular outflow tract. Furthermore, the rate of abnormal DRs in the left ventricular outflow tract in the observation group remained higher than that in the right ventricular outflow tract, right ventricular apex, and left ventricular apex, both before and after treatment. This is likely because type 2 diabetes patients experience persistent hyperglycemia and metabolic imbalances as the disease progresses, leading to cardiovascular damage and altered myocardial cell permeability, which may trigger various cardiovascular complications. Measuring DRs in diabetic patients effectively reflects vagal nerve function, thus assessing the status of myocardial and autonomic neuropathy (Xu, 2023). Compared with pre-treatment levels, ECG abnormality rates in the control group remained significantly lower than those in the observation group, and the ECG abnormality rate in the observation group was significantly lower post-treatment than pre-treatment. Specifically, VPC incidence in the observation group decreased in the right ventricular apex, right ventricular outflow tract, left ventricular apex, and left ventricular outflow tract after treatment (Wang, 2021). In addition, abnormal DRs in the left ventricular outflow tract remained consistently higher than in the right ventricular outflow tract, right ventricular apex, and left ventricular apex, both before and after treatment (Li, Huang, & Zhu, 2022). This may be due to the continuous hyperglycemia and disease progression in type 2 diabetes patients, resulting in metabolic imbalances and cardiovascular damage that alter myocardial cell permeability, ultimately causing cardiovascular diseases. Autonomic dysregulation and myocardial ischemia may lead to premature ventricular contractions. DRs technology in Holter electrocardiograms can assess the parasympathetic system's heart rate regulation and risk potential, which is essential for accurately evaluating cardiac autonomic regulation in type 2 diabetes patients (Zhu & Li, 2019). This aids in early identification of high-risk individuals with impaired neural function, thus preventing potential cardiovascular crises at an early stage.

The proximity of the left ventricular outflow tract to the aortic arch makes ventricular premature contractions in this region likely to alter ion channel sensitivity on cell membranes, inducing structural remodeling of myocardial cells, which disrupts normal myocardial depolarization and repolarization processes (Yang, 2023). Additionally, VPCs in the left ventricular outflow tract may weaken parasympathetic regulation of heart rate, reducing its protective function on the heart, causing DRs abnormalities, increasing the risk of severe arrhythmias, and posing a risk of sudden death.

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