

IMPACT OF DIABETES ON HEART RATE VARIABILITY AND LEFT VENTRICULAR FUNCTION IN PATIENTS AFTER MYOCARDIAL INFARCTION

Viktor Stoičkov, Stevan Ilić, Marina Deljanin Ilić, Aleksandar Nikolić, Vojislava Mitić

Institute for Prevention, Treatment and Rehabilitation of Rheumatic and Cardiovascular Diseases "Niška Banja",
Niška Banja

E-mail: viktors@bankerinter.net

Summary. Coronary patients with diabetes are at high risk of cardiovascular events. Coronary disease in diabetic patients has a rapid and progressive course due to the synergic activity of hyperglycemia and other risk factors of coronary disease such as dyslipidemia, hypertension, obesity, and smoking. Diabetic autonomic neuropathy which first affects the vagal nerves contributes to the bad prognosis of coronary patients with diabetes. The best marker of the state of activity of the autonomic nervous system is heart rate variability, which is a predictor of cardiac mortality. The aim of this study was to determine a possible influence of diabetes mellitus on the left ventricular function and the parameters of heart rate variability, as well as the relation between the left ventricular function and the parameters of heart rate variability in patients after myocardial infarction and diabetes.

We studied 141 patients after myocardial infarction in the sinus rhythm without AV blocks or branch blocks. Thirty-five patients had diabetes mellitus, and 106 did not. The average age of the patients was 58.82 years. Besides clinical examination and laboratory analyses, standard ECG, exercise test on a treadmill according to Bruce protocol, 24-hour holter monitoring, and echocardiographic examination were performed in each patient. Based on the holter record, the analysis of the heart rate variability was performed by software. Four parameters of the time domain heart rate variability were assessed: SDNN, SDANN, RMS-SD and NN > 50 ms.

Diabetic patients after myocardial infarction had a significantly lower values of the monitored parameters of heart rate variability, compared to those without diabetes (89.47 ± 30.82 vs. 103.28 ± 32.18 ms; $p < 0.025$ for SDNN; 28.50 ± 13.71 vs. 35.22 ± 12.42 ms; $p < 0.02$ for RMS-SD; 77.26 ± 27.58 vs. 88.74 ± 30.58 ms; $p < 0.05$ for SDANN and 7.45 ± 8.63 vs. 11.07 ± 9.08 ms; $p < 0.05$ for NN > 50 ms). Diabetics also had significantly lower values of LVEF (49.19 ± 8.01 vs. 52.84 ± 11.24 %; $p < 0.05$) and significantly higher values of LVEsD (39.39 ± 4.82 vs. 37.03 ± 6.18 mm; $p < 0.025$), as well as a higher degree of the left ventricle diastolic dysfunction, compared to non-diabetics (0.82 ± 0.18 vs. 0.91 ± 0.21 ; $p < 0.02$ for ratio E/A and 183.52 ± 47.29 vs. 214.32 ± 46.15 ; $p < 0.005$ for Dt). The study showed that there is a significant positive correlation of SDNN values and SDANN with LVEF ($r = 0.510$; $p < 0.01$ for SDNN and $r = 0.569$; $p < 0.01$ for SDANN) and a significantly negative correlation with LVEsD ($r = -0.361$; $p < 0.05$ for SDNN and $r = -0.364$; $p < 0.05$ for SDANN), while with LVEDd the correlation did not reach the level of significance in diabetic patients after myocardial infarction. The values of parameters RMS-SD and NN > 50 ms did not correlate significantly with LVEF or the internal dimensions of the left ventricle in diabetics after myocardial infarction.

The study demonstrated diabetic patients who suffered myocardial infarction have significantly lower values of the parameters of heart rate variability, significantly lower values of LVEF and significantly higher values of LVEsD, as well as a higher degree of the left ventricle diastolic dysfunction, compared to non-diabetics. The study showed that there is a significant positive correlation of SDNN and SDANN values with LVEF and a significant negative correlation with LVEsD in diabetics who suffered myocardial infarction.

Key words: Heart rate variability, left ventricle function, myocardial infarction, diabetes mellitus.

Introduction

Coronary patients with diabetes are at high risk of cardiovascular events which cause mortality in about 80% of diabetic patients. In the general population, there are 1-2% (1) to 5-8% (2) of patients with diabetes. In coronary care units, however, of all patients with acute coronary syndrome, there are about 20-25% of diabetic patients (3,4). The cause of such disproportion

is due to early development of atherosclerosis and coronary disease in diabetic patients, so it is more diffuse and of a more severe stage. Compared to non-diabetic coronary patients, three-vessel coronary disease is more frequent in diabetics, and fissures and thrombi more frequently form on atheromathosis plates (3,4,5).

Coronary disease in diabetic patients has a rapid and progressive course due to the synergistic influence of hyperglycemia and other risk factors of coronary dis-

ease, such as dyslipidemia, hypertension, obesity, and smoking. Besides coronary disease, diabetic cardiomyopathy is often present in diabetic patients (6,7). In diabetic patients without coronary disease, hypertension or dyslipidemia, systolic and diastolic dysfunction of the left ventricle have been found (8). Hyperglycemia increases the presence of renin and angiotensin in myocytes. Angiotensin II binds angiotensin receptors and induces apoptosis which contributes to the development of cardiomyopathy. Apoptosis of myocytes in the diabetic heart was characterized by an 85-fold increase (8).

Diabetic autonomic neuropathy which induces dysfunction of the autonomic nervous system is present in about 50% of diabetic patients (9) and contributes to the bad prognosis of coronary diabetics. The parameters of heart rate variability (HRV) as markers of the autonomic nervous system state are used for the evaluation of the influence of both the sympathetic and the vagus on the heart beat, as well as for the identification of patients who are at high risk of cardiovascular events (10,11,12).

Aim

The objective of the study is to determine a possible influence of diabetes mellitus on the left ventricle function and the parameters of heart rate variability, as well as the relation between the left ventricle function and the parameters of heart rate variability in diabetic patients who suffered myocardial infarction.

Patients and Methods

We examined 141 patients who suffered myocardial infarction (mean age 58.82 years) in the sinus rhythm without AV blocks or branch blocks. Thirty-five patients (24.8%) had diabetes mellitus, and 106 (75.2%) did not. There was no significant difference between the two groups with respect to age or sex. In diabetics who suffered myocardial infarction the average glycemia value was 11.2 ± 2.1 mmol/L, and the average cholesterol value was 6.4 ± 2.6 mmol/L. In patients without diabetes the average glycemia value was 4.7 ± 1.0 mmol/L, and the average cholesterol value was 5.8 ± 2.0 mmol/L. Cardiovascular risk factors in both groups are shown in Table 1.

Table 1. Some clinical characteristics in diabetic and non-diabetic patients who suffered myocardial infarction

Clinical characteristics	Patients with diabetes	Patients without diabetes	P
Mean age (years)	58.76 ± 7.81	58.84 ± 8.72	NS
Male sex	27 (77.14%)	78 (73.58%)	NS
Arterial hypertension	35 (100%)	69 (65.09%)	0.001
Cigarette smoking	27 (77.14%)	73 (68.87%)	NS
Hypercholesterolemia	18 (51.43%)	42 (39.62%)	NS

Besides clinical examination and laboratory analyses, standard ECG, exercise test, 24-hour holter monitoring and echocardiographic examination were also performed.

For the purpose of identifying residual ischemia, all patients underwent exercise testing, which was performed on a treadmill according to Bruce protocol. The test was terminated if one of the following criteria was met: attainment of age-specific maximal heart rate; occurrence of ≥ 0.2 mV horizontal or down-sloping ST-segment depression; reduction in systolic blood pressure > 20 mmHg from baseline; hypertension (blood pressure $> 240/120$ mmHg) or significant symptoms of arrhythmias. The test was considered positive if one of the following criteria was present on the ECG: horizontal or down-sloping ST-segment depression for ≥ 0.1 mV from the baseline ECG in three consecutive beats lasting more than 0.08 sec; ST-segment elevation for ≥ 0.1 mV from the baseline ECG in leads which do not have abnormal Q-wave.

A 24-hour holter monitoring (system Del Mar Avionics mode 5268-505 MPA/R-ACQ: 2.15, Irvine, California, USA) was performed during the patients' everyday activities. The system involved an analysis of the classic holter monitoring and defining of heart rate variability. Based on the holter records, the analyses of HRV were performed by software. Four parameters of the time domain HRV were assessed: SDNN (standard deviation of NN intervals during 24 hours), SDANN (standard deviation of the averages of NN intervals in all five-minute segments during 24 hours), RMS-SD (the square root of the mean of the sum of the squares of differences between adjacent normal RR intervals during 24 hours), NN >50 ms (percentage of consecutive RR intervals which differed for more than 50 ms during 24 hours).

The echocardiographic examination (Acuson-Sequia, C 256) was performed by M-mode and two-dimensional echocardiography and Doppler-echocardiography. The left ventricular end-diastolic diameter (LVEDd), the left ventricular end-systolic diameter (LVESd), thickening of the inter-ventricular septum (IVs), thickening of the posterior wall of the left ventricle (Pw), the size of the left atrium (La), and the left ventricular ejection fraction (LVEF) were measured. Transmitral diastolic blood flow was registered with the pulse Doppler from the apical position of the transducer, using the section of the four-chamber view. The sample volume was placed at the level of the top of the mitral leaflets in the open position. On the basis of the transmitral flow, the speed of the early (E) wave and late (A) wave of the atrial filling of the left ventricle were determined, as well as their ratio (E/A). The value of speed was expressed in cm/sec. Decelerate time of the early filling of the left ventricle (Dt) was also determined. The left ventricular systolic function was determined according to the value of LVEF and the internal dimensions of the left ventricle.

The results obtained were analyzed and statistically processed. The average value and standard deviation were determined for each parameter in both patients groups and tested by the Student t-test. The correlation of HRV parameters with the echocardiographic parameters of the left ventricle was determined.

Results

Diabetic patients who suffered myocardial infarction had significantly lower values of the monitored parameters of HRV, compared to those without diabetes (Table 2).

Table 2. Comparison of HRV parameters in diabetic and non-diabetic patients who suffered myocardial infarction

HRV parameters	Patients with diabetes	Patients without diabetes	t	p
SDNN (ms)	89.47 ± 30.82	103.28 ± 32.18	2.27	0.025
RMS-SD (ms)	28.50 ± 13.71	35.22 ± 12.42	2.57	0.02
SDANN (ms)	77.26 ± 27.58	88.74 ± 30.58	2.08	0.05
NN>50ms	7.45 ± 8.63	11.07 ± 9.08	2.13	0.05
RR (ms)	0.74 ± 0.11	0.79 ± 0.12	2.27	0.05

Patients with diabetes had significantly lower values of LVEF and significantly higher values of LVESd, as well as a higher degree of the left ventricle diastolic dysfunction, compared to patients without diabetes (Table 3).

Table 3. Comparison of echocardiographic parameters of the left ventricle in diabetic and non-diabetic patients who suffered myocardial infarction

Echocardiographic parameters of the left ventricle	Patients with diabetes	Patients without diabetes	t	p
LVEDd (mm)	55.71 ± 5.41	54.41 ± 6.02	1.20	NS
LVESd (mm)	39.39 ± 4.82	37.03 ± 6.18	2.34	0.025
IVs (mm)	12.14 ± 1.89	11.85 ± 2.43	0.73	NS
Pw (mm)	10.31 ± 1.43	10.59 ± 1.68	0.96	NS
La (mm)	42.18 ± 6.55	39.43 ± 6.35	2.17	0.05
LVEF (%)	49.19 ± 8.01	52.84 ± 11.24	2.10	0.05
E/A	0.82 ± 0.18	0.91 ± 0.21	2.43	0.02
Dt	183.52 ± 47.29	214.32 ± 46.15	3.36	0.005

The study showed that there is a significantly positive correlation of SDNN and SDANN values with LVEF and a significantly negative correlation with LVESd, while with LVEDd the correlation did not reach the level of significance in diabetics who suffered myocardial infarction (Table 4,5,6). The values of parameters RMS-SD and NN > 50 ms did not significantly correlate with LVEF and the internal dimensions of the left ventricle in diabetic patients after myocardial infarction (Table 4,5,6). Residual ischemia was present in

30 (85.7%) diabetics who suffered myocardial infarction and in 62 (58.4 %) non-diabetic patients.

Table 4. Correlation of LVEF with the parameters of HRV in diabetic and non-diabetic patients who suffered myocardial infarction (N=35)

HRV parameters	Average value	LVEF	
		r	P
SDNN (ms)	89.47 ± 30.82	0.510	0.01
RMS-SD (ms)	28.50 ± 13.71	- 0.017	NS
SDANN (ms)	77.26 ± 27.58	0.569	0.01
NN>50ms	7.45 ± 8.63	0.048	NS

Table 5. Correlation of LVEDd with the parameters of HRV in diabetic and non-diabetic patients who suffered myocardial infarction (N=35)

HRV parameters	Average value	LVEDd	
		r	p
SDNN (ms)	89.47 ± 30.82	-0.242	NS
RMS-SD (ms)	28.50 ± 13.71	0.176	NS
SDANN (ms)	77.26 ± 27.58	-0.256	NS
NN>50ms	7.45 ± 8.63	0.326	NS

Table 6. Correlation of LVESd with the parameters of HRV in diabetic and non-diabetic patients who suffered myocardial infarction (N=35)

HRV parameters	Average value	LVESd	
		r	p
SDNN (ms)	89.47 ± 30.82	-0.361	0.05
RMS-SD (ms)	28.50 ± 13.71	0.282	NS
SDANN (ms)	77.26 ± 27.58	-0.364	0.05
NN>50ms	7.45 ± 8.63	0.187	NS

Discussion

The study has shown that diabetic patients who suffered myocardial infarction have significantly lower values of HRV parameters, compared to patients without diabetes. Diabetics with myocardial infarction also had a significantly higher degree of the left ventricle dysfunction, compared to non-diabetics. A more severe degree of the left ventricle dysfunction in the examined diabetic patients is induced due to the synergistic influence of hyperglycemia, dyslipidemia and hypertension.

Hypertension has a significant role in the onset of coronary disease in diabetic patients. The lowering of blood pressure (average of 10/5 mmHg) using a beta-blocker or an ACE inhibitor as first line therapy reduced diabetes-related deaths by 32%, microvascular endpoints by 37%, strokes by 44%, and myocardial infarcts by 21% in patients with diabetes and hypertension (13). In our diabetic patients with myocardial infarction, arterial blood pressure was not controlled, which is one of the causes of the severe left ventricular dysfunction. Dyslipidemia is also a significant risk factor for coronary disease. It was shown that the level of cholesterol in coronary patients, during the period of 25 years of

monitoring, was directly correlated to mortality. Reduction of LDL cholesterol in coronary patients with diabetes leads to the decrease of morbidity and mortality (14). In our study, diabetics who suffered myocardial infarction had high values of cholesterol (6.4 mmol/L) which contributes to a faster progression of coronary disease. Besides the above-mentioned risk factors for coronary disease, smoking was present in a high percentage in our diabetic patients, which significantly accelerated the progression of coronary disease.

Diabetes is an independent risk factor for both morbidity and mortality. Patients with type II diabetes have two to four times higher risk of ischemic cardiovascular events in comparison to persons without diabetes, and the risk is mainly less dependent on concomitant hypertension, hyperlipidemia, and smoking (15,16,17). After control of all risk factors for coronary disease in patients with type II diabetes, the mortality rate of cardiovascular diseases is twice higher in men and four times higher in women (9). The correlation between fasting plasma glucose and the incidence of cardiovascular events is well established (15,16). Hyperglycemia induces cardiovascular dysfunction independent of arterial hypertension, dyslipidemia, and obesity. Hyperglycemia induces coronary dysfunction, because it takes part in producing free oxygen radicals which inactivate endothelium-derived nitric oxide and activate protein kinase C which induces production of vasoconstrictive prostanoids (17). Hyperglycemia induces endothelial dysfunction and increases platelets activity and their aggregability (17,18). In diabetic patients with non-regulated glycemia, the increased adhesion of platelets, monocytes and other leukocytes for endothelium were found. Fibrinogen and coagulability of blood were also increased, while fibrinolytic activity was decreased (19,20). In our study, diabetics who suffered myocardial infarction had high levels of glycemia (11.2 mmol/L). These patients had residual ischemia in high percent, found during the exercise test, which contributed to a greater left ventricle dysfunction. Patients with diabetes had significantly lower values of LVEF and significantly higher values of LVESd, compared to patients

without diabetes. These findings suggest a higher degree of the left ventricle systolic dysfunction in those patients. Diabetics who suffered myocardial infarction also had a higher degree of the left ventricle diastolic dysfunction, compared to patients without diabetes. Coronary disease and hypertension also contribute to the decrease of the left ventricle diastolic function in diabetic patients. However, in our study, non-diabetics also had coronary disease and arterial hypertension in a high percentage, but a significant difference in the wall thickness of the left ventricle between the two examined groups was not found. These findings suggest that, in addition to the above-mentioned causes, diabetic cardiomyopathy has a significant role in the development of a higher degree of the left ventricle dysfunction in diabetics.

In patients with diabetes, significantly lower values of HRV parameters which maintain the activity of vagus RMS-SD and NN > 50 ms were found, when compared to the values found in non-diabetics. This finding suggests that in diabetic patients, diabetic neuropathy is present in a great number of cases. Strict control of glycemia significantly reduces cardiovascular events and cardiac mortality in diabetics (19,21). In our study, all diabetics who suffered myocardial infarction had more than two risk factors for coronary disease, and most of them had residual ischemia which led to the increased lowering of the values of HRV parameters and to a great extent the left ventricular dysfunction.

Conclusion

The study has shown that diabetic patients who suffered myocardial infarction had significantly lower values of heart rate variability, significantly lower values of LVEF, significantly higher values of LVESd, and a higher degree of the left ventricle dysfunction, when compared to non-diabetic patients. There is a significant positive correlation of SDNN and SDANN parameters with LVEF, and a significantly negative correlation with LVESd, in diabetics with myocardial infarction.

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UTICAJ DIJABETESA NA VARIJABILNOST FREKVENCIJE SRČANOG RADA I FUNKCIJU LEVE KOMORE U BOLESNIKA SA PREŽIVELIM INFARKTOM MIOKARDA

Viktor Stoičkov, Stevan Ilić, Marina Deljanin Ilić, Aleksandar Nikolić, Vojislava Mitić

Institut za prevenciju, lečenje i rehabilitaciju reumatičkih i kardiovaskularnih bolesti "Niška Banja", Niška Banja

Kratak sadržaj: *Koronarni bolesnici sa dijabetesom su na visokom riziku od kardiovaskularnih događaja. Koronarna bolest u dijabetičara ima ubrzan, progresivni tok usled sinergističkog delovanja hiperglikemije i drugih faktora rizika koronarne bolesti, kao što su dislipidemija, hipertenzija, gojaznost i pušenje. Lošoj prognozi koronarnih bolesnika sa dijabetesom doprinosi i dijabetesna autonomna neuropatija koja prvo zahvata parasimpatikus. Najbolji marker stanja aktivnosti autonomnog nervnog sistema je varijabilnost frekvencije srčanog rada, koja je nezavisni prediktor kardijalnog mortaliteta. Cilj rada je da se utvrdi uticaj dijabetes melitusa na funkciju leve komore i parametre varijabilnosti frekvencije srčanog rada, kao i odnos funkcije leve komore i parametara varijabilnosti frekvencije srčanog rada kod bolesnika sa preživelim infarktom miokarda i dijabetesom.*

Studijom je obuhvaćen 141 bolesnik koji je preživeo infarkt miokarda, u sinusnom ritmu bez AV blokova i blokova grana. Sa dijabetes melitusom bilo je 35 bolesnika, a 106 je bilo bez dijabetesa. Prosečna starost ispitanika iznosila je 58,82 godine. Ispitanicima je pored kliničkog pregleda i laboratorijskih analiza urađen standardni EKG, test fizičkim opterećenjem na pokretnoj traci po Bruce-ovom protokolu, 24-časovni holter monitoring i ehokardiografski pregled. Iz holterskog zapisa softverski je vršena analiza HRV. Analizirana su četiri parametra vremenske analize HRV: SDNN, SDANN, RMS-SD i NN > 50ms.

Bolesnici sa preživelim infarktom miokarda i dijabetesom imali su značajno manje vrednosti praćenih parametara HRV u odnosu na one bez dijabetesa ($89,47 \pm 30,82$: $103,28 \pm 32,18$ ms; $p < 0,025$ za SDNN; $28,50 \pm 13,71$: $35,22 \pm 12,42$ ms; $p < 0,02$ za RMS-SD; $77,26 \pm 27,58$: $88,74 \pm 30,58$ ms; $p < 0,05$ za SDANN i $7,45 \pm 8,63$: $11,07 \pm 9,08$ ms; $p < 0,05$ za NN > 50 ms). Takođe, bolesnici sa dijabetesom imali su značajno manje vrednosti LVEF ($49,19 \pm 8,01$: $52,84 \pm 11,24$ %; $p < 0,05$), a značajno veće vrednosti LVESd ($39,39 \pm 4,82$: $37,03 \pm 6,18$ mm; $p < 0,025$), kao i veći stepen dijastolne disfunkcije leve komore u odnosu na one bez dijabetesa ($0,82 \pm 0,18$: $0,91 \pm 0,21$; $p < 0,02$ za odnos E/A i $183,52 \pm 47,29$: $214,32 \pm 46,15$; $p < 0,005$ za Dt). Studija je pokazala da postoji značajna pozitivna korelacija vrednosti SDNN i SDANN sa LVEF ($r = 0,510$; $p < 0,01$ za SDNN i $r = 0,569$; $p < 0,01$ za SDANN), a značajna negativna korelacija sa LVESd ($r = -0,361$; $p < 0,05$ za SDNN i $r = -0,364$; $p < 0,05$ za SDANN), dok sa LVEDd korelacija nije dostigla nivo značajnosti, kod bolesnika sa preživelim infarktom miokarda i dijabetesom. Vrednosti parametara RMS-SD i NN > 50 ms nisu značajno korelirale sa LVEF i unutrašnjim dimenzijama leve komore kod bolesnika sa preživelim infarktom miokarda i dijabetesom.

Studija je pokazala da bolesnici sa preživelim infarktom miokarda i dijabetesom imaju značajno manje vrednosti parametara varijabilnosti frekvencije srčanog rada i vrednosti LVEF, značajno veće vrednosti LVESd, kao i značajno veći stepen dijastolne disfunkcije leve komore, u odnosu na one bez dijabetesa. Postoji značajna pozitivna korelacija parametara SDNN i SDANN sa LVEF, a značajna negativna korelacija sa LVESd u bolesnika sa preživelim infarktom miokarda i dijabetesom.

Ključne reči: Varijabilnosti frekvencije srčanog rada, funkcija leve komore, infarkt miokarda, dijabetes melitus