Original article

Association between retinopathy, microalbuminuria and coronary perfusion in young patients with type 1 diabetes mellitus

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Abstract

Background: In patients with type 1 diabetes mellitus (DM) impairment of the coronary circulation has been observed. This phenomenon could be ascribed to the existence of a specific cardiomyopathy. Disturbances in other microcirculation beds – renal and ocular – are mirrored by microalbuminuria and retinopathy, respectively. The association between coronary microvascular dysfunction and the presence of microalbuminuria and retinopathy is not clear. Recognition of the interrelationships between microalbuminuria, retinopathy and the impairment of coronary circulation could allow for a simple estimation of coronary perfusion in these patients.

Aim: To assess coronary blood flow velocity in young patients with type 1 DM using transoesophageal Doppler echocardiography with dipyridamole and to analyse the possible relationship between the impairment of coronary flow and retinopathy as well as microalbuminuria.

Methods: The study group consisted of 36 patients, aged from 18 to 35 (mean: 25±5) years with type 1 DM lasting from 8 to 27 years. Diabetes was the only disease and none of the patients had any history of cardiovascular diseases or any abnormalities in physical examination. The control group consisted of 23 age-matched healthy volunteers. All subjects underwent transoesophageal echocardiography with dipyridamole to assess coronary flow velocity reserve (CFVR).

Results: In the study group CFVR and maximal flow velocity after dipyridamole were significantly decreased (2.4±0.6 vs. 3.4±0.7; p <0.001 and 125.7±31.4 vs. 168.00±12.9 cm/s; p <0.001, respectively). The basal flow velocity was comparable in both groups (55.9±14.6 vs. 52.2±11.6 cm/s; p=0.32). Decrease in CFVR in the study group was associated with a smaller increase in coronary flow velocity after dipyridamole challenge. There was no relationship between coexisting microalbuminuria, retinopathy and the CFVR values.

Conclusions: In young patients with type 1 DM, without any clinical cardiovascular abnormalities, decreased coronary perfusion is observed. The presence of microalbuminuria or retinopathy is not associated with the alterations in coronary perfusion.

Key words: type 1 diabetes mellitus, coronary flow reserve, transoesophageal echocardiography, Doppler

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Introduction

Diabetes mellitus (DM) is a strong and independent risk factor of cardiovascular disease (CVD). According to 2006 data, type 1 DM is associated with 3.5 times higher risk of coronary artery disease in men and 7.7 times higher risk in women [1].

Myocardial dysfunction may develop not only in patients with coexisting arterial hypertension and atherosclerosis but also in subjects with DM as a single clinical pathology [2]. These observations resulted in a hypothesis that DM may lead to specific myocardial injury, also called diabetic cardiomyopathy (DCM). The only feature of DCM is an impairment of the coronary microcirculation that may develop in the asymptomatic stage of disease in patients without other risk factors except for DM [3].

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Microalbuminuria is a sign of renal microcirculation dysfunction and currently is considered to be an independent predictor of cardiovascular events in diabetic patients [4]. Similarly, retinopathy reflects eye microcirculation abnormalities. The association between impaired coronary perfusion and microalbuminuria or retinopathy is currently not well defined. Finding a correlation between retinopathy or microalbuminuria and coronary flow disturbances would provide a relatively simple and attractive method of coronary microcirculation assessment in these patients.

Transoesophageal echocardiography (TEE) enables not only the evaluation of flow in proximal segments of coronary arteries but also, after administration of vasodilating agents, assessment of the coronary flow velocity reserve (CFVR). This method is currently used in the non-invasive evaluation of the coronary microcirculation in various clinical settings, including in our department [5-7].

The aim of this study was to evaluate the coronary flow parameters using Doppler TEE following dipyridamole administration in a group of young patients suffering from type 1 DM and to analyse any possible association between coronary perfusion disturbances and microalbuminuria or the presence of simple retinopathy.

Methods

All patients were informed about the aims and principles of the study, and expressed their written informed consent. The study protocol was approved by the Bioethical Committee of Poznań University of Medical Science.

Patients

This study involved 36 patients (18 men and 18 women) with established diagnosis of type 1 DM, aged 18-35 years (27±5 years), suffering from DM for an average of 16±5 years (8-27 years). Patients with DM lasting over 5 years, without a history of cardiovascular disease or any abnormal findings in the physical cardiovascular examination, were enrolled. Subjects with detected cardiac pathology and/or other serious chronic disease, arterial hypertension, symptomatic nephropathy (proteinuria), preproliferative and proliferative retinopathy as well as those taking medications other than insulin were excluded from the study. Patients were treated with insulin according to the two following protocols: 1) standard insulin therapy (n=13; two subcutaneous insulin injections per day) or 2) intensive functional insulin therapy (n=23; multiple insulin injections with adjusted dosing).

To evaluate the cardiovascular system the following examinations were carried out in each patient: standard 12-lead ECG at rest, 12-lead ECG exercise treadmill test according to Bruce protocol, M-mode, 2D and Doppler transthoracic echocardiography (TTE) [an assessment of cardiac dimensions, left ventricular (LV) volume, LV ejection fraction (LVEF), LV mass index (LVMI) and basic parameters of LV diastolic performance based on the Doppler mitral inflow measurements] and dobutamine stress echocardiography. Patients without any abnormal findings in these tests were selected for further analysis.

Laboratory test

Serum concentrations of fasting and 2 hours postprandial glucose, levels of total cholesterol, cholesterol HDL and LDL, triglycerides, creatinine and HbA_{1c} were measured. Patients were examined to detect simple retinopathy and diabetic nephropathy.

Urine albumin excretion (microalbuminuria) was measured in 12-hour, nocturnal urine. The result of this test was considered positive if urine albumin excretion was found within the range of 20 to 200 µg per minute detected in two of three consecutive examinations done within two months.

Microalbuminuria was detected in 14 (39%) patients, retinopathy in 24 (67%). The examined patient group was subsequently divided into two subgroups: ret– (without retinopathy signs) and ret+ (with retinopathy), or alb– (without microalbuminuria) and alb+ (with microalbuminuria).

Evaluation of retinopathy

Classification of retinopathy into the three following categories was adopted: simple retinopathy, preproliferative retinopathy and proliferative retinopathy [8]. In each individual with type 1 DM, ophthalmological examination was carried out to assess fundus of the eye in an attempt to find any signs of retinopathy. Absence of pathological findings was defined as a negative result while signs of simple retinopathy such as presence of microaneurysms, extravasations and solid exudates in various combinations and severities meant a positive result of the examination. Patients with preproliferative as well as proliferative retinopathy were excluded from the study.

Echocardiography

Echocardiographic examination was carried with a Sonos 5500 device (Agilent, Andower, USA) equipped with S3 probe for TTE tests and multiplane oesophageal transducer (Omniplane II) for TEE studies. Echocardiographic images were stored on magnetic-optical disks for further analysis. M-mode, 2D and Doppler echocardiography as well as echocardiographic dobutamine stress test were performed according to well established standards and guidelines [9].

The CFVR was calculated based on TEE Doppler with dipyridamole (TEE-D). Examination methodology in detail

was described in the previously published report [7]. The flow velocity in the proximal segment of the left anterior descending artery (LAD) was measured. Blood flow was assessed at rest (diastolic flow – V_{d-0} and systolic flow –V_{s-0}) and after dipyridamole administration in a total dose of 0.84 mg/kg body weight (systolic flow – V_{s-max} and diastolic flow – V_{d-max}). The final analysis involved only diastolic flow [10]; CFVR was calculated according to the following formula: CFVR = V_{r-max} /V_{r-0}.

Control group

It comprised 23 healthy volunteers (13 men and 10 women) aged 18 to 34 years (25±5 years). If no pathologies were detected in the history and when physical examination was accompanied by normal result of the echocardiographic examination, individuals were recruited to the study after written informed consent was expressed. Resting electrocardiography was carried out and blood glucose level evaluated in the control group.

Selected demographic and clinical data of patients as well as control individuals are shown in Table I.

Statistical analysis

Normal distribution of analysed variables was verified with Shapiro-Wilk test. Because the distribution of some of them was not normal, non-parametric tests were used in further analysis. The results are expressed as mean with standard deviation (SD) or as median with corresponding range for the parameters. Data in the charts are presented as mean (point), 25-75 percentile range ('frame') and minimum-maximum. To compare three groups, Mann-Whitney U and Kruskal-Wallis tests were used. The p value <0.05 was considered statistically significant. The correlations between selected variables within single groups were analysed using Spearman log rank test. Computer software Statistica for Windows, version 6.0 (StatSoft, Inc. 2001) was used.

Results

The Doppler TTE results in both groups are presented in Table II. Significantly lower end-diastolic dimensions of both cardiac ventricles as well as LV stroke volume were observed in patients than control subjects. Out of the parameters of mitral inflow reflecting LV diastolic function, higher A wave velocities and significantly decreased E/A ratios were noted in patients than in healthy volunteers. However, no differences between examined groups were found regarding LVMI and LVEF.

No correlations between studied parameters evaluated in TTE and indices of coronary flow were noted. Moreover, no impact of age, heart rate, or systolic and diastolic blood pressure (potential confounding variables) on the analysed parameters of coronary flow was seen.

Sixty-three subjects (both groups) underwent TEE-D examination. Acceptable visualisation of Doppler coronary velocity spectrum was achieved in 59 (93.7%) subjects (36 in type 1 DM patients and 23 in controls).

In the patient group, significantly lower values of both CFVR (2.4±0.6 vs. 3.4±0.7; p <0.001) and V_{r-max} (125.7±31.4 vs. 168.00±12.9; p <0.001) were observed while flow velocities at rest did not differ between groups (55.9±14.6 vs. 52.2±11.6; p=0.32). No significant correlations between parameters of coronary flow or duration of DM

Table I. Selected demographic and clinical characteristics of patients and control group

Parameter	Patients (n=36)		Control group (n=23)	
	mean±SD	median (min-max)	mean±SD	median (min-max)
Age [years]	27±5	27 (18-35)	25±5	24 (18-34)
Diabetes mellitus duration [years]	16±5	16 (8-27)	×	×
Heart rate [beats/minute]*	79±11	81 (51-100)	70±13	70 (52-95)
Systolic blood pressure [mmHg]*	120±7	121 (105-134)	113±7	112 (100-130)
Diastolic blood pressure [mmHg]*	76±7	76 (62-90)	69±6	70 (60-80)
Body mass index [kg/m^2]	23±3	23 (17-31)	22±2	22 (18-27)
HbA_{1c} [%]	8.4±1.9	8.0 (4.9-13.1)	×	×
Fasting glucose [mg/dl]*	167±64	160 (66-324)	87±8	87(71-104)
Glucose 2 h after meal [mg/dl]	159±64	153 (45-319)	×	×
Creatinine [mg/dl]	0.8±0.2	0.8 (0.6-1.2)	×	×
Total cholesterol [mg/dl]	187±36	191 (63-248)	×	×
Triglycerides [mg/dl]	111±43	107 (43-209)	×	×
HDL-cholesterol [mg/dl]	58±18	59 (21-105)	×	×
LDL-cholesterol [mg/dl]	107±30	111 (44-162)	×	×

**p <0.05 patients vs. control group*

Table II. Findings on transthoracic echocardiography in 36 patients with DM 1 and in 23 healthy individuals from control group

Parameter	Examined group	Control group	p
Cardiac structures			
right ventricular end-diastolic dimension [cm]	3.0±0.3	3.3±0.5	0.01
left ventricular end-diastolic dimension [cm]	4.5±0.1	4.9±0.4	0.004
left atrial dimension [cm]	2.9±0.3	3.0±0.4	NS
intraventricular septum dimension [cm]	0.9±0.1	0.9±0.1	NS
left ventricular posterior wall end-diastolic dimension [cm]	0.8±0.1	0.8±0.1	NS
left ventricular end-diastolic volume [ml]	82.8±20.4	89.4±33.2	NS
left ventricular end-systolic volume [ml]	54.2±13.9	63.1±17.7	NS
stroke volume [ml]	29.6±9.4	32.9±9.9	0.04
left ventricular mass index [g/m2]	69.5±13.0	77.0±14.7	NS
Evaluation of global contractility			
left ventricular ejection fraction [%]	64.1±6.7	66.5±6.1	NS
Assessment of diastolic performance			
wave velocity of early mitral inflow [cm/s]	76.3±15.1	78.3±15.5	NS
wave velocity of late mitral inflow [cm/s]	67.1±17.0	57.8±12.0	0.03
E/A index	1.2±0.3	1.4±0.4	0.03
deceleration time of E wave [ms]	145.6±34.7	134.6±25.9	NS
isovolumetric relaxation time [ms]	69.6±14.5	66.7±11.2	NS

Table III. Coronary flow velocity and coronary flow velocity reserve (CFVR) in the examined subsets of patients with diabetes mellitus and in the control group

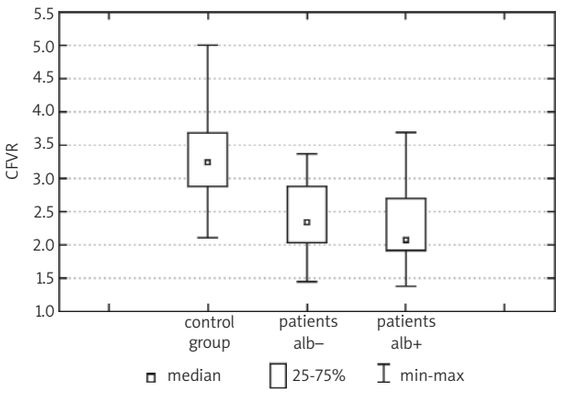
n	Subgroups	Mean±SD	Subgroups	Mean±SD
V_{r-0}				
23	control	52.2±11.6	control	52.2±11.6
12	patients alb–	52.7±16.2	patients ret–	51.5±11.6
24	patients alb+	57.5±13.7	patients ret+	62.8±16.4
V_{r-max}				
23	control	168.0±12.9	control	168.0±12.9
11	patients alb–*	119.5±26.6	patients ret–*	120.9±29.4
20	patients alb+*	129.2±33.9	patients ret+*	135.9±34.6
CFVR				
23	control	3.4±0.7	control	3.4±0.7
11	patients alb–*	2.5±0.4	patients ret–*	2.4±0.6
20	patients alb+*	2.3±0.6	patients ret+*	2.3±0.7

** p <0.05 patients group vs. control group*

and indices of long- or short-term glycaemic control were found.

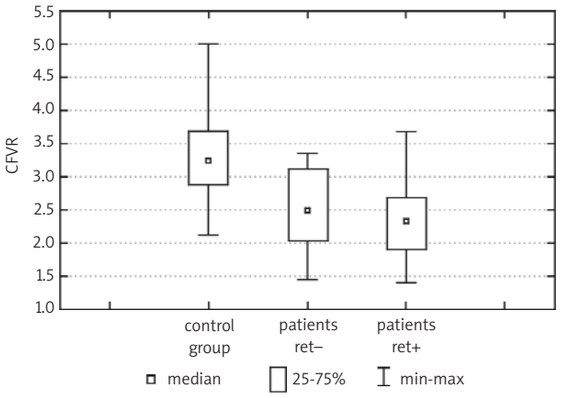
Concerning microalbuminuria, no differences between groups with respect to V_{r-0} velocity were observed. However, a trend towards higher V_{r-0} values in the subgroup of patients with microalbuminuria was seen. The V_{r-max} and CFVR values differed significantly between the control group and both subsets of patients, although no differences between patients with or without albuminuria were noted (Table III, Figure 1).

No differences between groups regarding V_{r-0} velocities with respect to the presence of retinopathy were documented. The V_{r-max} and CFVR values differed significantly between healthy individuals and both subgroups of patients, although no differences between patients with or without retinopathy were observed (Table III, Figure 2).



control group vs. patients alb– p <0.001; control group vs. patients alb+ p <0.001; patients alb– vs. patients alb+ NS

Figure 1. Coronary flow velocity reserve (CFVR) in patients and controls with respect to microalbuminuria



control group vs. patients ret– p <0.001; control group vs. patients ret+ p <0.001; patients ret– vs. patients ret+ NS

Figure 2. Coronary flow velocity reserve (CFVR) in patients and controls with respect to retinopathy

Discussion

In our study, a decreased CFVR in type 1 DM patients without symptoms of cardiovascular disease when compared to the group of healthy volunteers was found. Neither hypertension nor LV hypertrophy – abnormalities that might reduce CFVR – were noted [11, 12]. Reduction of CFVR in the patient group was also associated with less increase of blood flow velocity in response to dipyridamole stress. However, no significant differences regarding baseline flow velocity were noted.

Our findings are similar to those reported by other authors [3, 13, 14]. Pitkanen et al. [3] evaluated CFVR by means of a PET study in a group of 12 non-smoking men at the mean age of 30±6 years with a long history (14.4±4.7 years) of type 1 DM in comparison to a group of healthy subjects. They did not observe differences in resting flow parameters between examined groups but coronary flow (and in consequence coronary flow reserve) was decreased by 29% in the group of DM patients. Di Carli et al. [13] observed similar disturbances of the coronary microcirculation in both types of DM. They stressed the role of chronic hyperglycaemic state as a risk factor responsible for the development of microcirculation dysfunction. Sundell et al. [14] revealed an association between long-term HbA_{1c} levels and coronary artery reactivity.

Coronary flow velocity reserve is a marker reflecting the ability of vasculature to increase coronary blood flow in response to active reduction of vascular resistance provoked by increased myocardial oxygen demand or drop in coronary perfusion pressure [15]. Underlying mechanisms that regulate coronary flow are complex and not very well understood [16]. One of the substances regulating coronary blood flow is adenosine [17]. Endothelium-dependent and independent mechanisms are thought to have an impact on the final results during evaluation of coronary flow velocity using adenosine or dipyridamole. Dilatation of the coronary arterioles of a diameter of approximately 100 µm with adenosine administration (endothelium-dependent mechanism) causes a flow increase in the vessels of 100-400 µm diameter, which are responsible for approximately 40% of total coronary vascular resistance. Shear stress in these vessels resulting from flow increase leads to increased NO production and eventually their dilatation. In this mechanism, dilatation of the arterioles provoked by adenosine initiates endothelium-dependent mechanisms of vasodilatation [18].

In our study significant differences regarding parameters such as maximal flow velocity and CFVR between a group of young type 1 DM patients and healthy volunteers were seen, regardless of the presence of either retinopathy or microalbuminuria. These pathologies did not worsen existing abnormalities of the coronary flow – no differences were observed with respect to aforementioned flow parameters between the subsets of patients with or without studied complications. The findings of our study may indicate that coronary microcirculation dysfunction is not directly linked to simple retinopathy or microalbuminuria occurrence during the course of the disease, but rather it develops independently.

A reason for the lack of correlation may be different physiological properties of the particular microcirculation systems, i.e. in the eye or kidney vs. coronary circulation. Moreover, one should remember that examination of ophthalmic vessels is a test assessing 'morphology' of its microcirculation, contrary to the evaluation of CFVR, which reflects the functional changes that may precede morphological abnormalities. Microalbuminuria reflects

mainly damage of vascular endothelium, and due to different mechanisms determining coronary vessels' reactivity (endothelium dependent and independent), coronary microcirculation function may be preserved in spite of impaired endothelial function.

However, our results do not justify the conclusion that abnormalities in the vascular bed of the kidney and eye may be suitable markers of the changes in the coronary circulation in the course of type 1 DM. Similarly, Pitkanen et al. [3] did not observe any association between simple retinopathy and coronary microcirculation status. A few studies deal with the issue of a correlation between nephropathy development and coronary microcirculation dysfunction. Ragosta et al. [19], evaluating CFVR using an invasive method, noted higher resting flow in a group of patients with DM. However, they did not find any impact of isolated DM on CFVR; in fact it was markedly lower in a group with DM accompanied by renal failure. Abnormal results of CFVR were observed in 57% of patients with DM and renal failure, in 18% of subjects with diabetes but without renal failure, and in only 9% of individuals without DM.

Study limitations

This study involved a relatively small number of patients. It is not likely, although still possible, that decreased CFVR may result from significant stenosis of the coronary artery. Taking into account that examined patients were below 35 years of age and did not present with abnormal results of electrocardiographic stress test and echocardiographic test with dobutamine, the presence of significant lesions is really very unlikely. Coronary angiography was not carried out as no indications were found. Recently non-invasive assessment of the coronary reserve using TTE [20] has become possible. This examination is associated with less stress for examined patients and is less time-consuming.

Conclusions

Decreased coronary perfusion was observed in a group of young patients with type 1 DM free from any cardiovascular complications.

Development of simple retinopathy and microalbuminuria in this group of patients is not associated with progression of coronary microcirculation disturbances.

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Związek pomiędzy występowaniem retinopatii prostej i mikroalbuminurii a perfuzją wieńcową u młodych chorych na cukrzycę typu 1

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Streszczenie

Wstęp: W przebiegu cukrzycy typu 1 może dochodzić do zaburzeń mikrokrążenia wieńcowego, które są jednym z przejawów kardiomiopatii cukrzycowej. Mikroalbuminuria oraz retinopatia występujące u chorych na cukrzycę odzwierciedlają natomiast zaburzenia w obrębie mikrokrążenia nerek i oka. Związek między upośledzeniem mikrokrążenia wieńcowego a występowaniem mikroalbuminurii i retinopatii prostej jest niejasny. Wykrycie zależności pomiędzy retinopatią i mikroalbuminurią a zaburzeniami przepływu wieńcowego pozwoliłoby na dość prostą ocenę stanu mikrokrążenia wieńcowego u tych chorych.

Cel: Ocena parametrów przepływu wieńcowego w grupie młodych chorych z długoletnim wywiadem cukrzycy typu 1 przy użyciu doplerowskiej echokardiografii przezprzełykowej (TEE) z zastosowaniem dipirydamolu oraz analiza ewentualnego związku między zaburzeniami przepływu wieńcowego a obecnością mikroalbuminurii i retinopatii prostej.

Metodyka: Grupę badaną stanowiło 36 chorych na cukrzycę typu 1 (18 mężczyzn i 18 kobiet), w wieku 18–35 (średnio 25±5) lat, chorujących 8–27 lat. Do badania włączano chorych z rozpoznaniem cukrzycy typu 1 bez wywiadu w kierunku chorób serca i naczyń oraz bez odchyleń w badaniu przedmiotowym w zakresie układu sercowo-naczyniowego. Grupę kontrolną stanowiło 23 zdrowych ochotników w tym samym wieku. U wszystkich osób wykonano TEE z dipirydamolem w celu oceny rezerwy prędkości przepływu wieńcowego.

Wyniki: W badanej grupie w porównaniu z grupą kontrolną obserwowano istotnie niższe wartości prędkości przepływu wieńcowego (2,4±0,6 *vs* 3,4±0,7; p <0,001) i prędkości maksymalnej (125,7±31,4 *vs* 168,00±12,9 cm/s; p <0,001), natomiast wartości prędkości przepływu w warunkach podstawowych nie różniły się między grupami (55,9±14,6 *vs* 52,2±11,6 cm/s; p=0,32). Obniżenie prędkości przepływu wieńcowego w grupie badanej było związane z mniejszym przyrostem prędkości w odpowiedzi na obciążenie dipirydamolem. Nie obserwowano wpływu występowania mikroalbuminurii i retinopatii prostej na wartości prędkości przepływu wieńcowego.

Wnioski: W grupie młodych chorych na cukrzycę typu 1, bez klinicznych cech patologii układu sercowo-naczyniowego, obserwuje się obniżoną perfuzję wieńcową. Obecność retinopatii prostej i mikroalbuminurii w tej grupie chorych nie wiąże się z nasileniem zaburzeń mikrokrążenia wieńcowego.

Słowa kluczowe: cukrzyca typu 1, rezerwa przepływu wieńcowego, echokardiografia przezprzełykowa, badanie doplerowskie

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