Evaluation of effort tolerance in diabetic and non-diabetic patients undergoing cardiac rehabilitation after cardiac surgery

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Abstract

Introduction: Complex cardiac rehabilitation is a basic procedure of therapeutic treatment for patients after cardiac surgeries. The course of operations depends on many factors. The aim of this article is to investigate connections between type 2 diabetes and results of 6-minute walk test among patients after cardiac surgery.

Materials and methods: This research was conducted among 111 patients who had cardiac surgery. Those patients were qualified to stay at a stationary cardiac rehabilitation facility. They were divided into two groups: patients with and without diabetes. In the analysis, patients' medical data and 6-minute walk test results before and after complex rehabilitation were taken into consideration.

Results: On the basis of our analysis it was found that patients who have diabetes achieve worse results of 6-minute walk test before (OR=0.995; p=0.005) and after (OR=0.994, p=0.006) complex cardiac rehabilitation in comparison with patients without diabetes.

Conclusions: Type 2 diabetes has impact on physical effort tolerance among patients after cardiac surgery. Despite improvement of 6-minute walk test results thanks to complex cardiac rehabilitation, patients with type 2 diabetes walked shorter distance than patients without diabetes.

Keywords: cardiac rehabilitation, cardiology, 6-minute walk test, type 2 diabetes

Introduction

Complex cardiac rehabilitation is a basic procedure of therapeutic treatment for patients after cardiac surgeries [1]. Its actions are mostly aiming at reduction of the risk of secondary coronary incidents, as well as improvement of efficiency, functional abilities and life quality [2,3]. Its course depends on many factors. One of them is co-occurrence of diabetes among cardiological patients, which is an increasing health problem [1].

According to epidemiological data, there are 170 million people around the world who have diabetes [4]. It is believed that diabetes is strongly related to coronary disease, which is the most common illness within circulatory system. When someone has diabetes, it is 2-4 times more probable to have a coronary disease and that has a significant impact on results of cardiological patients' rehabilitation [5,6,7]. It is connected with faster progression of atherosclerosis of coronary arteries, higher probability of thrombotic incidents or endothelial dysfunction occurring in this group [5]. Moreover, adverse effects of hyperglycemia contribute to damage of function and structure of cardiomyocytes. It is connected with increase of free fatty acids and inhibition of uptake and release of glucose, which in consequence leads to decreased ability to transport oxygen to cardiomyocytes. Additionally, increased concentration of free radicals damage contractile proteins of the heart and increased collagen glycation level lead to myocardial stiffness, which can be the cause of ventricular dysfunction during diastole [6]. Patients with diagnosed diabetes who are qualified for cardiac surgery are burdened with higher perioperative risk and more rigorous therapeutic aims than patients without diabetes [1,8].

The main aim of this paper is to determine correlation between type 2 diabetes and 6-minute walk test results within patients after cardiac surgery incidents.

Material and methods

The study was conducted in SPSK2 Clinic of Cardiac Surgery of the Pomeranian Medical University in Szczecin. Patients who took part in the study had cardiac surgery with sternotomy. After surgery patients were qualified to stay at a stationary cardiac rehabilitation facility between March and December 2019. There were 111 patients who participated in the study – 87 (78.4%) men and 24 (21.6%) women. Their average age was 66.9 years old ($\pm$ 11.2). We assumed the following exclusion criteria: no complete data available in medical records, non-participation in stationary cardiac rehabilitation after surgery or contraindications to participation in cardiac rehabilitation.

Using medical reports, data including diagnosis, comorbidities, ejection fraction, C-reactive protein (CRP), creatinine (Cr), glomerular filtration rate (GFR), and glycated hemoglobin (HbA1c) were obtained. Moreover, in the study we used 6-minute walk test results which measure physical capacity. This test was conducted 2 times, when a patient was admitted to the rehabilitation department and just before he was going home. During the test measurements of blood pressure and pulse were also recorded.

6-minute walk test

A patient before 6-minute walk test is sitting in one place for 10 minutes in order to rest. When the patient is ready, the physiotherapist says "go" and the test is started. The patient then walks for 6 minutes in his own pace – not too slow, not too fast down the 30 metres long rehabilitation department hall, where start, turning spot and stop lines were earlier marked. Straight before and after the test, the physiotherapist measures the patient's blood pressure and pulse. When the patient feels chest pain, shortness of breath, has pale face or balance disorders, the test is interrupted and it is repeated when the clinical condition is stabilized.

Cardiac rehabilitation

The duration of complex rehabilitation in stationary mode was 3 weeks in cycles from Monday to Saturday. The forms of restoring physical strength were daily patting, breathing exercises performed 10 to 15 times per hour during the day using Triflo excerciser, anti-edema exercises of lower limbs every hour, walking down the corridor, training on cycloergometers as well as group exercises, which included equipment-free exercises, resistance and relaxing exercises and exercises for lower limbs on a rotor 6 times a day for 10-20 minutes.

Ethics and approvals

The study was conducted in accordance with the conditions of the Declaration of Helsinki. It received an approval from the Bioethical Committee of the Pomeranian Medical University (decision no. KB- 0012/16/01/19).

Analysis

Statistical analysis was performed using Statistica 13 software (StatSoft, Inc., Tulsa, OK, USA). The normality of quantitative data distribution was assessed using the Shapiro-Wilk test. Quantitative data were presented as mean, SD and median and evaluated using the Mann-Whitney U test.

Categorical variables were presented as proportions and analyzed using the Chi-squared test or Chi-square test with Yates correction. Univariate and multivariate logistic regression analysis was performed and presented as odds ratio with 95% confidence interval. Multivariate analysis was adjusted by age, sex, BMI and smoking. The p-value ≤ 0.05 was regarded as statistically significant. Data were also explored using data mining techniques, including rough sets.

Results

Characteristics of patients depending on the incidence of diabetes are demonstrated in Table 1. Mean value of glycated hemoglobin [%] in patients without diabetes was 5.86 (± 0.49) while in those with diabetes it was nearly 20% higher and reached the value of 7.03 (± 1.25). Difference between the groups was statistically relevant (p<0.001).

Moreover, patients with diabetes had mean plasma CRP concentration level of 6.16 mg/L (± 11.45), while in patients without diabetes that value was lower and reached 4.60 mg/L (± 8.39), with statistically relevant difference between the groups (p=0.038). Patients with diabetes had lower mean preoperative left ventricular ejection fraction [%] comparing to patients without diabetes (40.00 ± 9.20 vs 50.00 ± 10.63 respectively, p=0.007), but demonstrated greater improvement in ejection fraction after the surgery (45.00 ± 8.15 vs. 50.00 ± 10.63 in control group).

Table 1. Demographic data, medical history and selected parameters depending on the incidence of diabetes.

Demographic data		Without diabetes (n=77)	With diabetes (n=34)	p
Demographic data				
Age [years] (mean±SD; Me)		66.13±11.88; 67.00	68.74±9.21; 68.00	0.528
Sex (n, %)	male	61 (79.22%)	26 (76.47%)	0.941
	female	16 (20.78%)	8 (23.53%)	
BMI range (n, %)	normal	15 (22.39%)	7 (21.88%)	0.104
	overweight	36 (53.73%)	11 (34.38%)	
	obesity	16 (23.88%)	14 (43.75%)	
BMI (mean±SD; Me)		27.90±4.43; 27.78	28.97±4.43; 29.15	0.197
Smoking (n, %)		11 (30.56%)	3 (15.79%)	0.384

Medical history			
Heart failure (n, %)	62 (80.52)	32 (94.12%)	0.122
Arterial hypertension (n, %)	57 (74.03%)	29 (85.29%)	0.288
Renal failure (n, %)	14 (18.18%)	10 (29.41%)	0.283
Arrhythmias (n, %)	15 (19.48%	8 (23.53%)	0.817
COPD (n, %)	5 (6.49%)	2 (5.88%)	0.763
Preoperative parameters			
EF [%] (mean±SD; Me)	46.82±10.63; 50.00	40.83±9.20; 40.00	**0.007**
Glycated hemoglobin [%] (mean±SD; Me)	5.86±0.49; 5.80	7.03±1.25; 6.60	**<0.001**
CRP [mg/L] (mean±SD; Me)	4.60±8.39; 1.51	6.16±11.45; 2.92	**0.038**
Postoperative parameters			
EF [%] (mean±SD; Me)	47.05±10.86; 50.00	41.76±8.15; 45.00	**0.004**
CRP [mg/L] (mean±SD; Me)	248.33±95.13; 264.90	255.26±105.27; 249.24	0.995
GFR [ml/min/m2] (mean±SD; Me)	75.00±19.42; 79.50	71.64±21.94; 74.00	0.522
Creatinine [mg/dl] (mean±SD; Me)	1.04±0.31; 0.98	1.10±0.56; 0.97	0.744

Legend: n – number of patients, p – statistical significance, SD – standard deviation, Me – median, BMI – body mass index (kg/m^2), COPD – chronic obstructive pulmonary disease, CABG – coronary artery bypass grafting, CRP – C-reactive Protein, GFR – glomerular filtration rate.

In the study it was concluded that patients suffering from diabetes obtained significantly lower 6-minute walk test results both before (mean distance 238.00 ± 126.10 m, p=0.005) and after complex cardiac rehabilitation (mean distance 386.21 ± 120.15 m, p=0.006), comparing to control group (mean distance 307.70 ± 107.58 m, p=0.005 and 446.32 ± 87.33 m, respectively before and after rehabilitation). Detailed results are demonstrated in Table 2. Mean diastolic blood pressure at discharge from the rehabilitation department was 12% lower in patients with diabetes comparing to control group (p=0.028).

Table 2. 6-minute walk test results in patients with and without diabetes.

		Without diabetes (n=77)	With diabetes (n=34)	p
		mean±SD; Me	mean±SD; Me	
First 6-MWT distance [m]		**307.70±107.58; 330.00**	**238.00±126.10; 227.50**	**0.005**
Systolic pressure [mm Hg]	before	125.18±13.81; 127.00	128.41±13.38; 131.00	0.235
	after	136.61±17.20; 139.00	135.32±32.23; 136.50	0.849
Difference in systolic pressure [mm Hg]		11.68±12.54; 10.50	13.38±20.07; 11.50	0.651
Diastolic pressure [mm Hg]	before	75.26±9.51; 75.00	71.74±11.91; 70.50	0.098
	after	78.00±10.72; 77.50	**69.35±22.01; 69.50**	**0.028**
Difference in diastolic pressure [mm Hg]		3.30±7.64; 3.00	2.15±8.63; 2.00	0.253
Heart rate	before	78.95 ±10.46; 78.00	78.65 ±11.51; 83.00	0.836
	after	86.70 ±12.34; 88.00	87.71 ±14.26; 89.00	0.893
Difference in heart rate		7.61 ±8.46; 6.50	9.44 ±12.88; 6.00	0.954
Last 6-MWT distance [m]		**446.32±87.33; 448.00**	**386.21±120.15; 379.50**	**0.006**
Systolic pressure [mm Hg]	before	122.58±14.17; 123.00	124.03±13.34; 124.00	0.596
	after	139.66±18.16; 141.50	142.35±20.54; 140.00	0.691
Difference in systolic pressure [mm Hg]		17.74±15.17; 17.50	18.03±17.29; 20.00	0.859
Diastolic pressure [mm Hg]	before	69.48±9.43; 69.50	69.74±11.89; 67.00	0.977
	after	73.88±12.02; 74.00	74.06±12.92; 72.00	0.990

Difference in diastolic pressure [mm Hg]		4.40±9.60; 4.00	4.32±12.75; 3.50	0.997
Heart rate	before	70.32 ±10.04; 67.50	73.21 ±11.93; 71.00	0.300
	after	79.86 ±13.68; 76.50	80.15 ±12.86; 80.00	0.856
Difference in heart rate		9.54 ±7.59; 9.00	6.94 ±10.31; 9.00	0.593
Difference in 6-MWT distance [m]		**135.20±83.66; 110.00**	**144.41±74.48; 147.00**	**0.266**

Legend: n – number of patients, p – statistical significance, SD – standard deviation, Me – median, 6-MWT – 6-minute walk test.

Evaluation of relationships between 6-minute walk test results and incidence of diabetes was conducted. In patients with diabetes both the initial (OR=0.995; p=0.005) and final (OR=0.994; p=0.006) 6-minute walk test results were significantly lower. The regression analysis adjusted for age, sex, BMI and smoking confirmed the decrease in march distance in patients with diabetes, both in the initial (OR=0.994; p=0.049) and final measurements (OR=0.992; p=0.027), as illustrated in Table 3.

Table 3. Multifactorial regression analysis in patients with and without diabetes.

	Without diabetes (n=77)				With diabetes (n=34)		
	p-value	OR	CI -95%	Cl +95%	p-value	OR	Cl -95%
Not Adjusted							
Initial 6-MWT distance [m]	**0.005**	1.005	1.002	1.009	**0.005**	0.995	0.991
Final 6-MWT distance [m]	**0.006**	1.006	1.002	1.010	**0.006**	0.994	0.990
Adjusted							
Initial 6-MWT distance [m]	**0.049**	1.006	1.000	1.012	**0.049**	0.994	0.989
Final 6-MWT distance [m]	**0.027**	1.008	1.001	1.016	**0.027**	0.992	0.984

Legend: p – statistical significance, OR – odds ratio, CI– confidence interval, 6-MWT – 6-minute walk test.

Discussion

The relationship between the incidence of type 2 diabetes and 6-minute walk test results in patients after cardiac surgery procedures was examined in this study using statistics and other data mining techniques. In order to assess patients' physical performance, 6-minute walk test was used, combined with heart rate and arterial blood pressure measurements. It is a safe test that does not require specialist equipment and demonstrates each patient's functional state. This test also enables to measure the progress in physiotherapy process in subsequent treatment stages [9].

According to our study, it was concluded that diabetes affects physical effort tolerance in patients after cardiac surgery procedures. Patients suffering from type 2 diabetes obtained worse 6-minute walk test results both before and after the rehabilitation, comparing to patients without any carbohydrates metabolism disorders. This proves not only the unquestionably beneficial influence of rehabilitation in both groups, but also shows impaired physical performance in patients with concomitant type 2 diabetes.

Laddu et al. published an analysis of patients with diabetes who underwent cardiac rehabilitation, however with a difference in the form of complex rehabilitation and evaluated factors. Those patients were subjected to 12-week rehabilitation, which consisted of doing training for one hour twice a week with specialist supervision, doing individual exercise sessions, personalised health education and constant access to an interdisciplinary rehabilitation team. The study reported common occurrence of maximal metabolic equivalent (METs) and especially insulin resistance in patients with both ischemic heart disease and diabetes as well as patients without diabetes, enrolled in a complex rehabilitation program. After completing the program, the incidence of METs decreased and variuos cardiac-metabolic disorders improved. The improvement, however, was generally insubstantial among patients with diabetes, comparing to patients without diabetes [2].

Eser et al. concluded that immediate improvement in peak VO_2 after rehabilitation was similar in patients with and without diabetes. Nonetheless, in 12-months observation the maintenance of this improvement was worse in patients with diabetes, which was probably due to progress of the disease. These results were based on the examination of 1633 patients who underwent cardiac surgery procedures in eight European facilities and were subjected to cardiac rehabilitation [10].

Völler et al. concluded that complex cardiac rehabilitation program leads to optimization of cardiovascular risk factors both in diabetic and healthy patients [11]. This conclusion derived from the analysis of parameters of patients who suffered from acute cardiac incident and were subsequently subjected to cardiac rehabilitation which lasted about 23 days and consisted of physical exercise and dietetic counselling.

The influence of cardiac rehabilitation on physical and hemodynamic performance of patients with concomitant type 2 diabetes was assessed also by Głowacka et al. The difference in their approach was consisting in including in the study only patients who had had myocardial infarction. 47 patients qualified for 3 weeks of stationary rehabilitation were examined. Type 2 diabetes was found in 21 of them, and those patients were included in the study group. The rest of 26 patients were included in the control group. All patients were subjected to total of 15 training sessions five times a week, which consisted of: ergometer training, general rehabilitation gymnastics, psychoeducation and music therapy.

Basing on the analysis, it was observed that training time improved in both groups. Moderately better results were achieved by patients with no carbohydrates metabolism disorders, whose test time increased by 16%, while in patients with diabetes it decreased by 3%. Resting values of heart rate and arterial blood pressure were comparable in both groups. Beneficial results of cardiac rehabilitation were observed in both groups, but concomitant type 2 diabetes was related to worse physical performance and, thus, to worse rehabilitation outcomes [6].

Physical exercise has relevant impact on glucose level in serum, which is why it is recommended to people with impaired carbohydrate metabolism. Aerobic exercise performed at least 3-4 times a week for 20-60 minutes and involving large muscle groups of upper and lower limbs enable patients to maintain normal glucose level. Moreover, doing resistance exercise 2-3 times a week also has a positive effect on patients' condition.

According to Seguro C. et al. only 40 minutes of resistance exercise a week may contribute to improvement in general health condition and quality of life in patients with type 2 diabetes and arterial hypertension. They supported that claim with a case study in which they proved decrease in blood glucose level, systolic and diastolic blood pressure and resting heart rate in patients with coronary artery disease, type 2 diabetes and arterial hypertension, subjected to 15 weeks of resistance exercise [6,12].

The influence of physical activity in cardiac patients was also investigated by Denegri et al., who proved that cardiac rehabilitation program has a positive impact on glycemic control [13].

Conclusions

According to our analyses, type 2 diabetes influences physical effort tolerance in patients after cardiac surgery procedures. Despite the improvement of 6-minute walk test results due to complex cardiac rehabilitation, patients with type 2 diabetes walked significantly shorter distances in that test comparing to patients without diabetes.

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