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INFLUENCE OF THE ORIGINAL STATE OF THE LEFT VENTRICLE AND TECHNICAL FEATURES OF CORONARY ARTERY BYPASS SURGERY ON THE FUNCTIONAL SAFETY OF GRAFTS

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ABSTRACT

The goal of research is to study the influence of the initial state of left ventricular myocardium, as well as the technical features of the coronary artery bypass graft (CABG) on the prognosis of the functioning of coronary shunts.

Materials and methods. 46 men, who had CABG for stable angina class III, were examined. 23 of them had 2 type diabetes mellitus (DM2), 23 of them did not have carbohydrate metabolism disorders. On the eve of the surgery, all patients underwent transthoracic echocardiography to determine the indicators of left ventricular function. Information about the technical features of the CABG were taken from the surgical reports. One year after the surgery, all patients underwent a coronary and bypass angiography.

Results. Occlusion of coronary shunts was detected in 10 patients with DM2, and in 6 patients without DM2 (p value for Fisher's exact test is 0.177). A larger left ventricle end-diastolic and end-systolic diameter (p value for the Mann-Whitney test is 0.004; 0.012), as well as a larger left ventricle end-diastolic and end-systolic volume (p value for the Mann-Whitney test is 0.012; 0.006) were associated with the presence of coronary shunt occlusions in patients with DM2. Also in the group of patients with DM2, sequential venous shunts were significantly more frequently occluded (p value for Fisher's exact test is 0.004). Dysfunctioning shunts were associated with abovementioned figures among patients without carbohydrate metabolism disorders.

Conclusion. The results of the research confirm the mutual confounding influence of risk factors on the prognosis after CABG.

Keywords: *coronary artery bypass graft, diabetes mellitus, sequential bypass graft.*

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INTRODUCTION

AThe high frequency at which occlusion of coronary shunts occurs is one of the most important problems of coronary surgery. According to the data in the literature, up to 20% of shunts function unsatisfactorily as early as the hospital stage [1]. Given the massive scale on which cardiac surgery is carried out, this becomes a problem for a large number of patients.

Identification of the factors instrumental in developing dysfunction of coronary shunts would allow the formation of risk groups among patients after coronary artery bypass grafting (CABG) and would allow the issue of secondary prevention to be approached on a case-by-case basis.

Currently, the influence of systolic and diastolic functions of the left ventricle on the prognosis in patients with coronary heart disease is well-studied. The final systolic and diastolic sizes of the left ventricle are predictors of adverse cardiovascular events in patients with multi-vascular hemodynamically significant damage to the coronary arteries [2, 3]. According to a study by D.L. Priop et al., the final systolic volume of the left ventricle is a predictor of mortality for patients after CABG. Moreover, the ejection fraction and the final diastolic volume of the left ventricle failed to prove prognostic significance [4]. However, the question of the functional state of the left ventricle influencing the likelihood of coronary bypasses becoming occluded remains open.

The proper functioning of the shunt is largely dependent on the condition of the target coronary bed, including the diameter of the shunt artery. S. Goldman et al. have found that the diameter of the shunted vessel of more than 2 mm ensures that of 88% of shunts have normal patency 10 years after CABG. When the diameter of the shunted vessel is less than 2 mm, only 55% of the shunts functioned satisfactorily after 10 years [5]. According to R.C. McLean et al., the diameter of the shunted vessel of 1.5 mm or less [6] might be a predictor of vein graft thrombosis. The stenosis degree of the shunted vessel also affects the shunt function: with proximal stenosis of less than 70%, the risk of shunt occlusion increases significantly [7].

Literature data on the functional safety of shunts with sequential anastomoses are inconclusive. In 2011, the results of a meta-analysis were published, indicating the best functional safety of coronary shunts with sequential anastomoses [8]. In 2019, information was published on a population-based study conducted in Denmark with 24,742 patients. The authors report a higher mortality rate and a higher risk of shunt thrombosis in cases of sequential shunting [9]. The data obtained during the study of the register SWEDEHEART are less categorical – the use of sequential bypass strategy often leads to adverse cardiovascular events in the early postoperative period. At the same time, medium-term CABG results do not differ in patients with sequential and in patients with exclusively linear shunts [10].

It had been previously established that a longer duration of cardiopulmonary bypass during coronary artery bypass grafting contributed to an increase in overall mortality, greater frequency of strokes and more cases of heart failure, both in the early postoperative period and in the long-term operation period [11, 12]. Moreover, the effect of the CABG operation duration and cardiopulmonary bypass on the function of shunts needs to be studied.

The purpose of this paper is to study what effect the initial state of the left ventricular myocardium, as well as the technical features of the operation have on the prognosis for the functioning of coronary bypass grafts.

MATERIAL AND METHODS

The study was conducted in 2016–2018, and is cohort, prospective. 46 men were examined who had been operated on for a stable course of chronic coronary heart disease. All patients underwent coronary artery bypass grafting under cardiopulmonary bypass. Twenty-three patients were individuals with type 2 diabetes mellitus (T2DM), twenty-three were individuals without carbohydrate metabolism disorders.

The groups did not significantly differ in age, height, weight, body mass index. Significant differences were revealed only along the circumference of the waist (Table 1).

Table 1. Comparison of patients with T2DM and patients without T2DM for a number of clinical features

Feature in question	Patients with T2DM (N=23). Me (P_{25}; P_{75})	Patients without diabetes (N=23). Me (P_{25}; P_{75})	P for the Mann-Whitney test
Age, years	59 (55; 64)	58 (61; 65)	0.221
Height, cm	172.5 (167; 175)	170 (168; 178)	0.711
Weight, kg	88 (76; 99)	82 (72; 99)	0.252
BMI, kg/m^2	28.8 (25.3; 33.3)	26.8 (25.8; 30.7)	0.175
Waist circumference, cm	103 (95; 112)	89(80; 95)	**0.000**

Note to Table 1. BMI – Body mass index. Me – median, P_{25}; P_{75} – upper and lower quartiles. In bold, p stands for statistically significant differences.

The number of patients who had previously undergone MI in the group of patients with T2DM was 17, in the group of patients without T2DM – 21, there were no significant differences in this indicator between the groups (p for the Fisher test=0.121). There were also no differences in the incidence of arterial hypertension (p for the Fisher test=1.000) – 19 patients, respectively, in both groups.

1–2 days before CABG surgery, all patients underwent transthoracic echo- cardiography, which included determining the size and functional state of the left ventricle (LV): final diastolic size (FDS), final systolic size (FSS), final diastolic volume, final systolic volume (FSV), stroke volume (SV), myocardial mass (MM) and ejection fraction (EF). The tactics of surgical myocardial revascularization (the feasibility of shunting a particular vessel, as well as the possibility of using this or that conduit) were determined by the operating surgeons in each case individually based on the clinical situation. Information on the technical features of each intervention was obtained from the protocols of operations.

One year after CABG, all patients underwent coronary artery bypass grafting to assess shunt patency.

Statistical methods. The distribution type of quantitative continuous data was assessed by calculating the Shapiro-Wilk criterion. To compare the groups by quantitative characteristics, the Mann-Whitney test and the Kruskal-Wallis test were used. To compare the groups by qualitative binary characteristics, χ^2 with Yates correction and a two-sided version of Fisher's exact criterion were applied. The critical value of the significance level is $p < 0.05$.

RESULTS

According to the results of coronary shuntography, a year after the operation, shunt occlusions were revealed in 10 patients with T2DM and in 6 patients without T2DM. There were no significant differences in the frequency of occlusions – Fisher test=0.033, p=0.177. There were no cases of occlusion of two or more shunts in one patient.

All the patients were divided into 4 groups depending on the presence of type 2 diabetes mellitus and the presence of occlusions of coronary bypass grafts one year after surgery. Group I – patients with type 2 diabetes without occlusion; group II – patients with T2DM and shunt occlusions, group III – patients without

Table 2. Echographic parameters of the left ventricular myocardium before coronary bypass surgery

Feature	I. Patients with T2DM without occlusion, n=13. Me (P_{25}; P_{75})	II. Patients with T2DM with occlusions of shunts n=10. Me (P_{25}; P_{75})	III. Patients without diabetes without occlusions n=17. Me (P_{25}; P_{75})	IV. Patients without diabetes with occlusions of shunts n=6. Me (P_{25}; P_{75})	Kruskal-Wallis test; p
FDS, cm	4.9 (4.6; 5.3)	5.6 (5.4; 5.9)	5.3 (5.0; 5.9)	5.7 (5.5; 5.8)	H= 9.424 P=0.024
FSS, cm	3.3 (3.1; 3.4)	3.95 (3.7; 4.3)	3.9 (3.4; 4.2)	4.4 (3.8; 5)	H=9.232 P=0.026
FDV, ml	112 (103; 134)	150.5 (143; 170)	148 (116; 173)	161.5 (145; 175)	H=9.969 P=0.047
FSV, ml	44 (39; 47)	68.5 (59; 84)	69 (48; 85)	72.5 (73; 95)	H=9.239 P=0.026
SV, ml	68 (61; 81)	80.5 (78; 85)	71 (59; 81)	85.5 (68; 85)	H=5.003 P=0.172
MM, g	219 (210; 274)	286 (264; 318)	261 (237; 302)	346 (280; 378)	H=6.645 P=0.084
EF, %	64 (56; 66)	55.5 (51; 58)	54 (48; 60)	52.5 (47; 59)	H=6.655 P=0.088

Note to Table 2. Me – median, P_{25}; P_{75} – upper and lower quartiles. FDS - final diastolic size, FSS - final systolic size, FDV - final diastolic volume, FSV - final systolic volume, SV stroke volume, MM - myocardial mass, EF - ejection fraction. In bold, p stands for statistically significant differences.

carbohydrate metabolism disorders and without shunt occlusions; and IV – patients without carbohydrate metabolism disorders with shunt occlusions. All the groups were compared according to the following indicators of LV myocardial function – FDS, FSS, FDV, FSV, SV, EF and MM. The comparison results of the indicators before surgery are presented in Table 2.

Statistically significant differences between the groups were revealed in the FDS, FSS, FDV and FSV. For these indicators, a pairwise comparison of the four groups was carried out. It was revealed that group I was significantly different from group II (p for the Mann-Whitney test, respectively, 0.004; 0.012; 0.012; 0.006) and from group IV (p for the Mann-Whitney test, respectively, 0.012; 0.009; 0.022; 0.022). That is, in the patients with shunt occlusions, the size and volume of the left ventricle was significantly larger than in the patients with T2DM without shunt occlusions. This means that among the patients with type 2 diabetes, high values of FDS, FSS, FDV and FSV can act as predictors of coronary bypass occlusions. Moreover, group III and IV did not significantly differ in the cited indicators (p for the Mann-Whitney test, respectively, 0.391; 0.177; 0.516; 0.811). Therefore, among the patients without diabetes, large LV volume and size were not associated with a high likelihood of shunt occlusion.

A total of 46 patients received 100 shunts – 50 patients with T2DM (16 arterial and 34 venous) and 50 patients without T2DM (22 arterial and 28 venous). The groups did not significantly differ in the number of arterial and venous shunts – X^2=1.06; p=0.303.

The condition of the target coronary bed. In both the patients with T2DM and in the patients without diabetes, the relationship between the condition of the target coronary bed and the results of CABG was evaluated. The results are presented in Table 3.

According to the data obtained, the stenosis diameter and stenosis degree of the shunt arteries were not associated with the development of coronary shunt occlusions in the long-term period of the operation.

As it turned out, the basin of the shunted vessel is of great importance for predicting the functioning of coronary shunts. Of the 100 shunts studied, 75 were placed on the branches of the left coronary artery (LCA), and 25 to the right coronary artery (RCA) or to its branch, i.e. the posterior interventricular artery. 8 shunts belonging to the LCA basin and 8 shunts to the RCA basin proved to be occluded. Consequently, the shunts to the RCA system were closed significantly more often (χ^2=6.35; p=0.012).

Sequential anastomoses. All the observed cases of sequential shunting were performed only with the use of venous conduits, i.e., arterial sequential shunting was not used in the studied group of patients. Of the 34 venous shunts imposed on the patients with T2DM, 12 had sequential anastomoses. A year after the operation, only 6 of them functioned satisfactorily, 6 were occluded, respectively. At the same time, a year after the operation, out of the 20 linear shunts only one was closed. That is, in the

Table 3. The condition of the target coronary bed and its effect on the results of coronary bypass surgery

Feature	I. Shunts of the patients with T2DM without occlusions n=40; Me (P_{25}; P_{75})	II. Shunts of the patients with T2DM with occlusions of shunts n=10; Me (P_{25}; P_{75})	III. Shunts of the patients without diabetes without occlusions n=44; Me (P_{25}; P_{75})	IV. Shunts of the patients without diabetes with shunt occlusions n=6; Me (P_{25}; P_{75})	Kruskal-Wallis test
Diameter of the shunt artery, mm	2 (2; 2.5)	2 (2; 2.25)	2 (2; 2.5)	2 (2; 2.25)	H=2.236 P=0.525
Proximal shunt artery stenosis, %*	85 (60; 95)	80 (70; 95)	80 (60; 90)	80 (70; 95)	H=1.200 P=0.753

*Note to Table 3. Me – median, P_{25}; P_{75} – upper and lower quartiles. * – the stenosis degree of the coronary arteries was estimated in %, subocclusions were taken into account as 95% stenosis, occlusions as 100% stenosis.*

Table 4. The influence of some technical features of coronary bypass surgery on long-term results of the operation

Feature	I. Patients with T2DM without occlusions, n=13; Me (P_{25}; P_{75})	II. Patients with T2DM with occlusions of shunts n=10; Me (P_{25}; P_{75})	III. Patients without diabetes without occlusions n=17; Me (P_{25}; P_{75})	IV. Patients without diabetes with shunt occlusions n=6; Me (P_{25}; P_{75})	Kruskal-Wallis test
The time of surgery, min	235 (190; 245)	227.5 (197.5; 272.5)	240 (210; 260)	195 (165; 275)	H=1.861 P=0.602
Cardiopulmonary bypass, min	82 (59; 102)	117 (95; 123)	81 (59; 110)	71 (66; 86)	H=5.875 P=0.118
Aortic occlusion time, min	49.5 (29.5; 55.5)	66 (57; 86)	47 (37; 64)	44.5 (38; 50)	H=5.824 P=0.126

Note to Table 4. Me – median, P_{25}; P_{75} – upper and lower quartiles.

examined patients with T2DM, venous sequential shunts are closed significantly more often than venous linear shunts – p for the Fisher test = 0.004.

In the group of patients without diabetes, there were 7 sequential venous shunts, 21 linear ones. A year after the operation, 2 sequential and 2 linear shunts were occluded. In contrast to the patients with diabetes, in this group of the testees, there was no association between the presence of sequential anastomoses and occlusion of venous shunts – p for the Fisher test = 0.253.

The duration of the intervention. According to the data obtained, such aspects of the operation as its duration, cardiopulmonary bypass and aortic occlusion time, did not affect the long-term prognosis of shunt functioning (Table 4).

DISCUSSION

Among the studied patients with T2DM, a statistical relationship was established between large volume and size indicators of LV before surgery and a high probability of shunt occlusion. Among the patients without diabetes, such a pattern was not found. Since the prognostic significance of FDS, FSS, and FSV in relation to adverse cardiovascular events in the patients with coronary artery disease has been proven, there is a reason to believe that this pattern is also valid for predicting the functioning of shunts. The increased risk of cardiovascular events in such situations might be due to myocardial remodeling and a change in its local contractility. It is reasonable to assume the negative impact of the myocardial remodeling on the hemodynamics of shunts. The question of how exactly the shunt thrombosis unfolds under the current conditions requires further study.

In the present study, no statistical relationship was found between the diameter of the shunted vessel, the degree of its proximal stenosis and the prognosis of the functioning of coronary shunts. On the face of it, this contradicts the data in the literature. However, of the 100 shunts studied, only 7 had a diameter of less than 2 mm. Proximal stenosis of less than 70% occurred in only 14 shunted vessels. Rare cases of shunting small arteries and arteries with stenosis of less than 70% can be regarded as adequate tactics of operating surgeons.

The shunts that revascularize the system of the right coronary artery, according to the data obtained, "close" more often than the shunts associated with the left coronary artery district. The data in the literature partially confirm this. After conducting a meta-analysis of 52 studies, A.C. Pinho-Gomes et al., concluded that arterial shunts associated with the right coronary artery district are occluded significantly more often. There were no significant differences with respect to venous shunts, therefore, the authors of the meta-analysis insist on further study of this issue [14].

According to the results of this study, sequential venous shunts in the patients with diabetes are significantly more likely to undergo occlusion in comparison with linear ones. But this pattern is not observed in patients without diabetes. Since the literature on the functional safety of sequential shunts is contradictory, we can assume the presence of unaccounted for additional factors that adversely affect the function of the sequential shunt. Diabetes might well be such a factor.

According to the results of this study, echographic indicators of left ventricular myocardial function and the presence of sequential anastomoses are predictors of coronary bypass occlusions only in the group of the patients with T2DM. The revealed statistical pattern confirms the idea of shunt occlusion as a multifactorial event: it is not one single risk factor that leads to an adverse outcome, but a combination of factors (in this context, those are diabetes and other factors).

CONCLUSIONS

1. Among the patients with T2DM, persons with occlusions of coronary bypass grafts had significantly higher rates of FDS, FSS, FDV and FSV determined before surgery compared with the patients without occlusion.
2. Coronary shunts were more often occluded to the right coronary artery district in comparison with shunts to the left coronary artery district.
3. Sequential venous shunts in the patients with T2DM were significantly more likely to be occluded than linear shunts. However, the total number of anastomoses and the number of peripheral anastomoses was not associated with the likely occlusion of coronary bypass grafts.
4. The influence of cardiopulmonary bypass time, aortic occlusion time, and total CABG duration on the prognosis of coronary bypass grafting has not been established.

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