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Contents

First Experience of Retrograde Myocardial Perfusion for Endovascular Correction of Complex Lesions of the Anterior Coronary System in Patients with Acute Coronary Syndrome

E.B. Shakhov[1,2], B.E. Shakhov[2], D.V. Petrov[1], A.Ya. Kosonogov[1], K.A. Kosonogov[1], D.V. Volkov[1], A.S. Novikov[1]*

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Support of coronary blood flow during endovascular correction of complex coronary lesions is the principal objective. The patients aged from 45 to 68 y.o. were included in our study. To support the blood supply of left ventricle during correction of complex lesions of the anterior coronary system, retrograde perfusion of the anterior left ventricle wall was performed. Significant favorable impact of myocardial retroperfusion on the primary parameters of central hemodynamics including heart rate and systolic blood pressure was observed in all examined patients. The patients supported with retroperfusion demonstrated significant decrease in ST-elevation compared to non-retroperfusion electrocardiography data in thoracic leads.

Key words: *retroperfusion, adjuvant blood supply, complex coronary lesions, endovascular surgery, acute coronary syndrome.*

Objectives. To evaluate the efficacy of retrograde myocardial perfusion for prolonged correction of complex lesions of the anterior coronary system in ACS patients.

Background. The support of coronary blood flow for endovascular correction of complex stenoses and occlusions of the anterior coronary system is the principal objective.

Methods. From October 07, 2013 till February 01, 2014 the results were analyzed from 5 patients who were admitted to State-Funded Healthcare Institution City Clinical Hospital No 5 of Nizhniy Novgorod and underwent radioendovascular correction of the complex lesions of the anterior coronary system. The patients aged from 45 to 68 y.o. (mean age = 56.6 ± 9.6 y.o.) were enrolled in our study. To support the blood supply of the myocardium during prolonged correction of the complex lesions of the anterior coronary system, selective retrograde perfusion of the anterior left ventricle wall was performed. During retroperfusion support, hemodynamic, electrocardiographic (height of ST segment in 6 chest leads) and echocardiographic parameters were assessed.

Results. During retroperfusion, already after 60 seconds without antegrade blood flow through the anterior coronary system we proved significant decrease in *ST*-elevation compared to angioplasty without coronary blood flow support (*ST* in leads V_4-V_6 with retroperfusion – 2.9 ± 0.07 mm; *ST* in leads V_4–V_6 without retroperfusion – 0.8 ± 0.7 mm; p = 0.011). During the study we observed significant increase in systolic blood pressure with retroperfusion support (136.4 ± 27.1 mmHg, p = 0.043) compared to SBP without retroperfusion (108.6 ± 24.3 mmHg) and trend to increase in mean blood pressure and HR.

Conclusions. The method of temporary selective retroperfusion of the great cardiac vein may be used as an adjuvant option of myocardium blood supply during angioplasty of complex coronary lesions.

Abbreviations

ACS – acute coronary syndrome
LV – left ventricle
PCI – percutaneous coronary intervention
LCA – left coronary artery
LAD – left anterior descending artery
DB – diagonal branch
PTBC – percutaneous transluminal coronary balloon angioplasty
MAP – mean arterial pressure
SBP – systolic blood pressure
HR – heart rate
IPmCS – mean invasive pressure in coronary sinus
ECG – electrocardiography

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EF – ejection fraction
LCII – local contractility impairment index
LVDF – left ventricle diastolic function
SPmBR – mean systolic pressure in retroperfusion system during selective catheterization of the proximal part of the great cardiac vein before retroperfusion
SPMmBR – mean maximum systolic pressure in retroperfusion system during selective catheterization of the proximal part of the great cardiac vein before retroperfusion
SPmR – mean systolic pressure in retroperfusion system during selective catheterization of the proximal part of the great cardiac vein during retroperfusion
SPMmR – mean maximum systolic pressure in retroperfusion system during selective catheterization of the proximal part of the great cardiac vein during retroperfusion
SBP – systolic blood pressure
MAP – mean arterial pressure
EchoCG – echocardiography

Relevance

Modern pharmacoinvasive strategy for patients with acute coronary syndrome (ACS) is aimed at maximally early restoration of adequate myocardial blood supply via primary percutaneous radioendovascular intervention in the infarct-related coronary artery. Despite continuous development of radiodiagnostics and X-ray surgical methods of treatment, advancement of tools for percutaneous interventions and significant reduction of "door-balloon" time, the in-hospital mortality related to acute coronary infarction in the national healthcare institutions remains very high, up to 16.7% (1). Among principal reasons for such disappointing statistics are technical difficulties during endovascular correction of complex coronary lesions in ACS patients (2).

Thus, the incidence of atherosclerotic lesions at the anterior coronary system which are difficult for endovascular correction, is consistently rising and achieves up to 30-40% (4, 5, 6, 7). The selection and practical application of optimal interventional approach for each specific type of complex lesions of the anterior coronary system delay achievement of adequate antegrade myocardial perfusion and are associated with risk of prolonged disorder in blood supply of the main functional volume of the left ventricle (LV), thus resulting in higher mortality in patients during primary PCI (3).

Support of coronary blood flow during endovascular correction of complex stenoses and occlusions of the anterior coronary system is the primary objective forcing scientists worldwide to develop new approaches for myocardial protection (9).

Achievement of maximally possible support of myocardial blood flow during correction of complex lesions of the anterior coronary system is related to application of specific technical solutions, which largely determine clinical outcomes of primary PCI and are still not clear enough in modern medical practice.

The study objective is to evaluate the efficacy of retrograde myocardial perfusion for prolonged correction of complex lesions of the anterior coronary system in ACS patients.

Methods

From October 07, 2013 till February 01, 2014 the results were analyzed from 5 patients who were admitted to State-Funded Healthcare Institution City Clinical Hospital No 5 of Nizhniy Novgorod and underwent radioendovascular correction of the complex lesions of the anterior coronary system. The patients aged from 45 to 68 y.o. (mean age = 56.6 ± ± 9.6 y.o.) were enrolled in our study. There were 4 men and 1 woman. In all patients examined by us, at the moment of the first admission for medical care, acute coronary syndrome was preliminary diagnosed: ST-elevation ACS in 1 patient only; non-ST-elevation ACS in 4 patients.

Our study included the patients who had at least one lesion of the anterior coronary system at selective coronarography, which was difficult for endovascular correction (Table 1).

The complex lesions of the anterior coronary system were determined as follows: lesions of the left main coronary artery (LMCA), proximal bifurcation lesions of the left anterior descending artery (LAD) and diagonal branches (DBs), LAD occlusion (10, 11, 12, 13, 14). The severity of coronary lesions was additionally assessed using Syntax Score (15).

Our study focused on investigation of patients with acute disturbances of coronary blood supply corrected within the first 90 minutes after admission at the hospital (mean time 'door-balloon" in our study was 74.8 ± 18.5 minutes). The patients who did not meet these criteria were excluded.

The diagnostic and treatment endovascular interventions were performed in X-ray surgical rooms equipped with angiographic devices "Innova 3100-IQ" (GE Medical Systems, France), where ACS patients were transferred

Table 1. Characteristics of the complex lesions of the anterior coronary system in ACS patients

Patients #	Complex lesions			Associated lesions of the posterior coronary system	Syntax Score (points)
	LMCA lesions (Yes/No)	Proximal bifurcation lesions (Yes/No)	Occlusions (Yes/No)		
1	Yes	Yes	No	Yes	33.0
2	No	Yes	Yes	Yes	22.0
3	No	Yes	Yes	Yes	30.5
4	Yes	Yes	Yes	Yes	54.0
5	Yes	Yes	No	No	24.0

immediately from the therapeutic admission department. Prior to intervention, the patients received loading dose of clopidogrel (300 mg), heparin 10,000 U was intravenously infused to achieve activated clotting time (ACT) at the level of 350–490 seconds.

Prior to intervention, the right or left common femoral artery was punctured to access coronary arteries with the purpose to perform balloon angioplasty and/or stenting. Standard sheath 7 Fr was inserted into the common femoral artery.

To support the blood supply of left ventricle (LV) during prolonged correction of the complex lesions of the anterior coronary system, selective retrograde perfusion of the anterior left ventricle wall was performed. The right/left subclavian or jugular vein was punctured and then the delivery system 8 Fr was placed into the ostium of the coronary sinus. The standard dual-lumen retroperfusion balloon catheter 6 Fr (Swan–Ganz type) was selectively placed over the delivery system to the proximal part of the great cardiac vein collecting the blood from the LV anterior wall. While the great cardiac vein was selectively catheterized, the right or left radial artery was punctured for autologous arterial blood collection and standard radial sheath 5 Fr was placed into the artery.

During coronary intervention we tried to correct atherosclerotic coronary lesion as completely as possible and achieve antegrade coronary blood flow TIMI 2–3. The primary objective was to restore antegrade blood flow TIMI 2-3 in the infarct-related anterior coronary system. During intervention all hemodynamically significant coronary lesions (stenoses > 60%) underwent at least one catheter balloon angioplasty (CBA) for 60–70 seconds. CBA was considered to be adequate if residual stenosis was <60%. Just before stent implantation in the zones of residual stenoses of the anterior coronary system, retrograde perfusion of the left ventricle anterior wall was started. Prior to retroperfusion, the balloon was dilated through one of the lumens of retroperfusion balloon catheter till complete occlusion of the proximal segment of the great cardiac vein, then the free inner lumen of the retroperfusion balloon catheter was attached to perfusion device BP-05 (Avangard, Russia). To collect arterial autologous blood, perfusion device was connected to arterial sheath placed in the radial artery. Retroperfusion time corresponded to the time of antegrade blood flow occlusion during stent placement (60–70 sec). The rate of retroperfusion when the antegrade blood flow in the anterior coronary system was blocked did not exceed 40 mL/min. Given the possibility of selective catheterization of the great cardiac vein responsible for reverse blood supply of the left ventricle anterior wall, retroperfusion was not synchronized with cardiac diastole and was performed continuously till restoration of adequate antegrade blood flow through LAD and DBs. This retroperfusion technique is original and promotes selective retroperfusion of symptom-related ischemic myocardial zone.

During retroperfusion support of myocardial blood supply, the following homodynamic parameters were determined: mean arterial pressure (MAP); systolic blood pressure (SBP); heart rate (HR); mean invasive pressure in coronary sinus (IPmCS). The ST height was measured in 3 standard and 6 thoracic electrocardiographic (ECG) leads to control the efficacy of retroperfusion support and endovascular intervention. Hemodynamics and ECG parameters were assessed in patients before and during retroperfusion support using diagnostics complex GE Healthcare Mac-Lab/SpecialsLab 6.8 (GE Medical Systems, USA) and compared to evaluate the efficacy of the intervention.

The efficacy of temporary arterialization of the great cardiac vein was determined via measurement of free hemoglobin in the blood serum at the retroperfusion output. Moreover, pH and oxygen partial pressure in the arterial

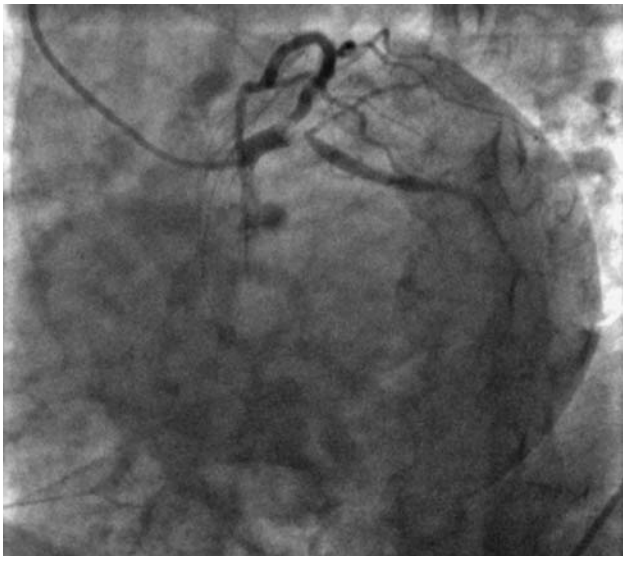

Figure 1. Complex coronary lesions: Subtotal bifurcation stenosis of the left main coronary artery.

Figure 2. Selective catheterization of the great cardiac vein and contrast phlebography.

autologous blood and arterial hemoglobin oxygen saturation were measured during retroperfusion. The assays were performed using diagnostic equipment ABL800FLEX (RADIOMETER, Denmark). Prior to endovascular intervention and just after it, markers of myocardial injury were assessed (Troponins T and I) using laboratory equipment Cobas h 232 (Roche, Germany) and DxPress Reader (Life Sign's, USA).

Echocardiography (EchoCG) and Doppler cardiography were performed before and after intervention in all patients. The tests were performed using GE Vivid 7 Pro (GE Medical Systems, Norway) with transducers 3.0 MHz and 3.5 MHz. During these tests special attention was paid to such echocardiographic parameters of the LV function as ejection fraction (EF), local contractility impairment index (LCII), vE/vA parameter (diastolic function).

Statistical processing was performed using licensed software STATISTICA 8.0. The results are presented as M ± sd, where M – mean value, sd – standard deviation. To analyze the study results, non-parametric statistical analysis of the obtained data was performed using paired Wilxocon test to compare two dependent variables and Friedman rank dispersion analysis (ANOVA). P values of <0.05 were considered as statistically significant. Statistically insignificant values were presented as $p > 0.05$ (16).

Results

During diagnostic coronarography all patients had symptom-related lesions in the anterior coronary system (Table 1). Acute occlusive thrombotic lesions were diagnosed in 3 cases: acute occlusions located in the proximal parts of LAD were predominant. The baseline antegrade blood flow through the anterior coronary system in these cases was assessed as TIMI 0. The trunk lesions were also diagnosed in 3 cases: stenoses >80% were visualized in the distal part of the left main coronary artery in 2 patients; stenosis 70% – in the middle segment of the trunk in one patient. The baseline antegrade blood flow through the anterior coronary system in these cases was assessed as TIMI 1–2 (Figure 1).

The bifurcation lesions were diagnosed in all examined patients and represented by stenoses >70% types 1.1.1. and 0.1.0 according to Medina classification. The baseline antegrade blood flow through the anterior coronary system in these patients was assessed as TIMI 2. The concomitant lesions of the posterior coronary system were diagnosed in 4 patients (80.0%) and represented by stenoses from 50% to 90%. During radioendovascular intervention all 5 patients (100.0%) underwent successful radioendovascular correction of symptom-related lesions of the anterior coronary system and hemodynamically significant lesions (stenoses >50%) of the posterior coronary system. The antegrade blood flow through the anterior coronary system after endovascular intervention in all examined patients significantly increased up to TIMI 3 ($p = 0.005$).

Catheterization of the main cardiac vein and selective catheterization of the great cardiac vein to prepare the retroperfusion myocardial support were successful in all 5 (100%) patients (Figure 2).

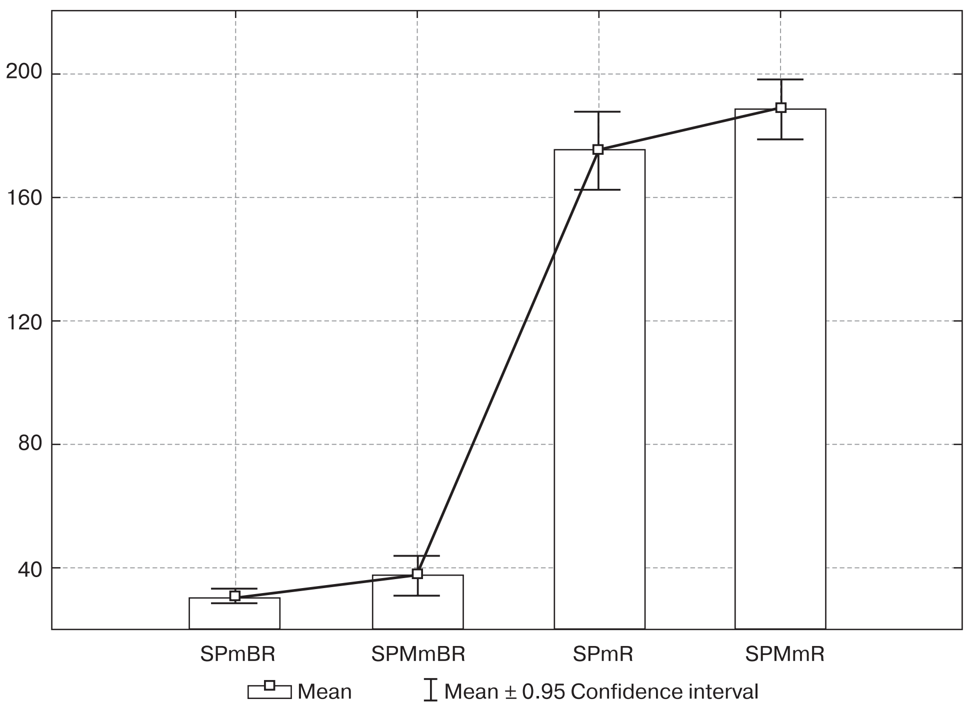

Figure 3. Mean systolic and maximum systolic pressure in the great cardiac vein before and during retroperfusion support (mm Hg): SPm – mean systolic pressure; SPMm – mean maximum systolic pressure; BR – before retroperfusion; R – retroperfusion.

Mean time of the selective catheterization of the proximal part of the great cardiac vein via subclavian access was 13.6 ± 2.7 minutes. During catheterization of the venous heart system, a complication – extravasation at the distal part of the main cardiac vein when the retroperfusion catheter was inserted through its kink, was observed in 1 case only. Extravasation did not result in vein rupture or hemopericardium. There were no disturbances of venous drainage through the coronary sinus or arrhythmic complications during coronary vein catheterization and retroperfusion support.

During phlebography mean dimension of the proximal part of the main cardiac vein was 8.73 ± 2.02 mm, mean dimension of the proximal part of the great cardiac vein was 3.66 ± ± 0.51 mm. Prior to retroperfusion, mean systolic pressure (SPmBR) and mean maximum systolic pressure (SPMmBR) in the retroperfusion system when proximal part of the great cardiac vein was selectively catheterized were 30.4 ± 1.8 mmHg and 37.5 ± 5.1 mmHg, respectively. During endovascular intervention associated with retrograde support of coronary blood flow, mean systolic pressure (SPmR) and mean maximum systolic pressure (SPMmR) in retroperfusion system significantly increased compared to baseline values up to 175.2 ± 9.17 mmHg and 188.6 ± 7.82 mmHg, respectively ($p = 0.043$) (Figure 3).

Significant favorable impact of myocardial retroperfusion on primary parameters of central hemodynamics including heart rate (HR) and systolic blood pressure (SBP) was observed in all studied patients. When there was no retroperfusion support, a trend to decrease in mean arterial pressure (MAP) was observed in the patients (Table 2).

During intraoperative electrocardiographic (ECG) monitoring all examined patients demonstrated significant signs of myocardial

Table 2. Primary parameters of the central hemodynamics in patients with complex lesions of the anterior coronary system

Hemodynamic parameters	Occlusion of the antegrade blood flow during angioplasty/stenting for 60 sec		Significance (p)
	Without retroperfusion	With retroperfusion	
HR (bpm)	65.6 ± 5.7	77.6 ± 14.1	0.043
MAP (mmHg)	83.4 ± 22.6	96.6 ± 14.2	0.177
SBP (mmHg)	108.6 ± 24.3	136.4 ± 27.1	0.043

Table 3. Dynamics of *ST* and *T* wave magnitude during intraoperative ECG in patients with complex lesions of the anterior coronary system

Thoracic leads	Baseline, intervention start		Angioplasty without retroperfusion support		Angioplasty with retroperfusion support		Significance (p)
	ST	*T*	*ST*	*T*	*ST*	*T*	
V_1–V_3 (mm)	1.1 ± 0.9	5.2 ± 2.2	2.2 ± 1.0	7.7 ± 3.0	1.3 ± 1.0	5.4 ± 2.3	0.027
V_4–V_6 (mm)	0.6 ± 0.9	6.8 ± 3.5	2.9 ± 0.07	9.5 ± 2.1	0.8 ± 0.7	6.1 ± 4.4	0.011

Table 4. Primary EchoCG parameters in patients with complex lesions of the anterior coronary system

EchoCG parameters	Before intervention	One day after intervention	Significance (p)
EF, %	51.6 ± 5.9	59.6 ± 5.6	0.043
LCII	1.10 ± 0.13	1.05 ± 0.11	p > 0.05
LVDF	0.84 ± 0.07	0.92 ± 0.14	0.22

Table 5. Changes in laboratory parameters in patients with complex lesions of the anterior coronary system

Laboratory parameters	Prior to retroperfusion support	After retroperfusion support	1 day after intervention	Significance (p)
Troponin T (ng/ml)	0.810 ± 1.030	1.406 ± 1.027	0.436 ± 0.300	p > 0.05
Troponin I (ng/ml)	0.773 ± 1.063	1.240 ± 1.140	0.200 ± 0.173	p > 0.05
Free hemoglobin (g/l)	0.01 ± 0.01	0.01 ± 0.01	0.03 ± 0.005	p > 0.05

ischemia, i.e. ST-elevation in thoracic leads at Second 60 after occlusion of antegrade blood flow in the anterior coronary system during angioplasty. At the repeat 60-second occlusion of the antegrade blood flow in the anterior coronary system under retroperfusion myocardial support, significant decrease in ST-elevation compared to non-retroperfusion ECG was observed in thoracic leads (Table 3).

During echocardiographic (EchoCG) monitoring all patients demonstrated significant improvement of ejection fraction (EF) one day after endovascular correction of complex coronary lesions with retroperfusion support of myocardial blood supply. Furthermore, these patients demonstrated a trend to improvement of local contractility impairment index (LCII) and left ventricle diastolic function (LVDF) (Table 4).

Analysis of changes in myocardial injury markers (troponin T, troponin I) and free hemoglobin in the patients' blood demonstrated no significant differences of the studied parameters before, after and 1 day after myocardial retroperfusion, suggesting no damage due to our local support of coronary blood flow (Table 5).

Arterial autologous blood pH (pH 7.365 ± 0.04) and partial oxygen pressure in arterial autologous blood (pO_2 205.00 ± 21.21 mmHg), as well as arterial hemoglobin oxygen saturation (sO_2 99.7 ± 0.14%) measured at the retroperfusion output suggest an effective (for retroperfusion support) oxygenation of arterial autologous blood.

Discussion

Our study proved the efficacy of retrograde myocardial perfusion in patients with acute coronary syndrome during endovascular correction of complex lesions in the anterior coronary system. For the first time, concept of endovascular approach to retrograde myocardial perfusion was stated by Meerbaum et al. in 1975 (17). Since then, series of preclinical and clinical studies were conducted to confirm the safety and efficacy of retrograde perfusion in patients with unstable angina and one-vessel atherosclerotic coronary lesion (18, 19). Later on, Kar et al., Constantini et al. confirmed the efficacy of reperfusion to support myocardial blood supply and pioneered in using this type of adjuvant myocardial blood flow for complications of endovascular interventions associated with fatal complications (20, 21).

In our study we used our own modification of the known method, namely selective retrograde perfusion of the myocardium supplied with blood from the anterior coronary system, in the setting of temporary occlusion of antegrade blood flow through LMCA and LAD during angioplasty of complex coronary lesions. Such approach allowed myocardial perfusion via selective temporary arterialization of the great cardiac vein not affecting blood drainage through other cardiac veins and coronary sinus.

To prove efficacy of our method, we paid special attention to electrocardiographic changes in the left ventricle anterior wall. In contrast to opinions of Berland J., Farcot J.C. et al., who tried to prove the key role of echocardiography for assessment of intraoperative efficacy of retroperfusion support, our study demonstrated leading diagnostic value of electocardiography during intervention (22). We agree with opinions of Hauser A.M., Gangadharan V., et al. and consider electrocardiographic criteria of myocardial ischemia to be the earliest markers of myocardial changes during long-term occlusion of antegrade blood flow through the anterior coronary system (23). During retroperfusion, already after 60 seconds without antegrade blood flow through the anterior coronary system we proved significant decrease in ST-elevation compared to angioplasty without coronary blood flow support (ST in leads V_4–V_6 with retroperfusion – 2.9 ± 0.07 mm; ST in leads V_4–V_6 without retroperfusion – 0.8 ± 0.7 mm; $p = 0.011$).

We were able to observe the most clear and significant EchoCG changes in the left ventricle systolic and diastolic parameters only 1 day after intervention. The changes in EF and LVDF observed in our study help to comprehensively evaluate only an effect of restoration of the antegrade blood flow in the anterior coronary system and indirectly suggest absence of significant damage due to retrograde perfusion (pre-intervention EF – 51.6 ± 5.9%; EF 1 day post-intervention – 59.6 ± 5.6%; $p = 0.043$).

During the study we observed significant increase in systolic blood pressure related to retroperfusion support (136.4 ± 27.1 mmHg, $p = 0.043$) compared to SBP without retroperfusion (108.6 ± 24.3 mmHg) and trend to increase in mean arterial pressure and HR. It may be explained by partial resolving of myocardial ischemia during occlusion of the antegrade blood flow and restoration of LV normal function related to retroperfusion support.

Troponin T and I values did not significantly increase after intervention (1.406 ± 1.027 ng/ml and 1.240 ± 1.140 ng/ml, respectively, $p > 0.05$) compared to baseline values (0.810 ± ± 1.030 ng/ml and 0.773 ± 1.063 ng/ml, respectively). Such changes were observed one day after intervention, thus suggesting no trend to pathological changes in myocardial infarction markers; their activity peaks 18–48 hours after endovascular correction. Of course, based on troponin T and I values we can't reliable assess possible harmful effects of retroperfusion support (24). On the contrary, arterial free hemoglobin concentration (0.01 ± 0.01 g/l) at retroperfusion output as well as primary blood acid-base parameters suggest the lack of hemolysis related to retroperfusion support and show adequate capability of perfused arterial autologous blood for myocardial oxygenation (24).

Conclusions

The method of temporary selective retroperfusion of the great cardiac vein may be used as an adjuvant option for blood supply of the myocardium perfused by the anterior coronary system if antegrade blood flow is interrupted for a short time during angioplasty of complex coronary lesions. In cases of interventions on the left main coronary artery or proximal part of the left anterior descending artery, retroperfusion support decreases ischemic myocardial changes associated a risk of fatal events. Intraoperative electrocardiographic data show significant decrease in ST-elevation during selective myocardial retroperfusion. Changes in the primary echocardiographic parameters of the left ventricle as well as myocardial damage markers demonstrate a trend to restoration of myocardial physiology in the area of intervention. Analysis of acid-base balance of arterial autologous blood demonstrates the safety and adequacy of the original retroperfusion technique to provide temporary myocardial support.

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Balloon Valvuloplasty of Stenosed Tricuspid Valve Bioprosthesis (A clinical case)

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We present a case of transluminal balloon valvuloplasty (TBVP) of tricuspid valve bioprosthesis with technical details of the procedure and data of examination at day 2, in 1 month and 6 months after the procedure. EchoCG revealed stenosis of tricuspid valve bioprosthesis with relevant clinical signs. After endovascular intervention cardiac indices and patient's condition improved. Positive dynamics persisted for 6 months. The signs of restenosis of tricuspid valve bioprosthesis appeared during the last month and have been confirmed by physical examination and EchoCG data.

Hence, transluminal balloon valvuloplasty of tricuspid valve bioprosthesis allows to achieve immediate positive results. In the presented case the results persisted for a rather short period (6 months).

***Key words:** valvuloplasty, balloon valvuloplasty, tricuspid valve bioprosthesis, stenosis of tricuspid valve bioprosthesis, restenosis, restenosis of bioprosthesis, restenosis of tricuspid valve bioprosthesis.*

Until rather recently, surgical correction under extracorporeal circulation remained the sole method for the management of stenosed tricuspid valve. The first cases of transluminal balloon valvuloplasty (TBVP) use for the correction of stenosed tricuspid valve bioprosthesis date of the end of the 20th century – Wren C., Hunter S. (1989)., Attubato M.J., Stroh J.A. (1990). This method is used very seldom, due to the high rate of early restenosis (1, 2, 3, 4).

The aim of this report was to demonstrate a case of stenosed tricuspid valve bioprosthesis management using TBVP.

The patient F., male, 34 years old, was admitted to the department of cardiac surgery with the complaints of marked dyspnea, palpitations, weakness, legs edema. He had a history of three valve replacement for infective endocarditis 6 years ago. The mitral valve was replaced by MedInj -31 prosthesis, the aortic valve – be MIKS – 23 and the tricuspid valve – by PeriCor-31 prosthesis. The patient's condition was aggravated by severe heart failure (NYHA class IV), hemorrhagic vasculitis treated by permanent hormonotherapy, fibrous liver changes and chronic heart failure.

At admission his condition was moderately severe, the skin was pale and dry. On auscultation there were harsh breath sounds over all fields, precordial auscultation revealed typical murmurs of valvular prostheses. ECG showed sinus rhythm with heart rate of 100 bpm, horizontal deviation of electrical heart axis, the signs of right atrial dilatation. EchoCG revealed thickened, fibrous, deformed, calcified cusps of bioprosthetic tricuspid valve with decreased opening amplitude, right atrial dilatation (5,4 × 5,0 cm). Pulsed wave Doppler study demonstrated diastolic pressure gradient up to 22 mm Hg, the orifice area 0,7 cm^2. There was no signs of aortic and mitral valve dysfunction.

With the consideration the presence of severe concomitant diseases, the high risk of complications in case of reoperation under extracorporeal circulation, the probability of early degradation of a new bioprosthesis (due to young age of the patient), we decided to perform transluminal balloon valvuloplasty of stenosed bioprosthetic triculaspid valve under local anesthesia.

A guidewire EmeraldGuidewire 0,035" Cordis was advanced to the right ventricle through the right subclavian vein under multiprojection X-ray and EchoCG guidance. The balloon TYSHAK II Numed 22 × 20 mm chosen for valvulplasty could not be advanced through tricuspid valve prosthesis with a guidewire 0,035" because of insufficient guidewire support and the severity of stenosis. After numerous attempts, the guidewire 0,035" was replaced by Amplatzer 002 (Fig. 1). Predilatation was performed with the balloon catheter Opta PRO 8 × 60 mm. The balloon was inflated at 4 atm and exchanged to TYSHAK II Numed balloon 22 × 20 mm, which was advanced to the tricuspid valve. Valvuloplasty was carried put at 1 atm (RBP 2 atm). The balloon was inflated to receive the isthmus in the valve = 16 mm, after that EchoCG demonstrated a decrease of

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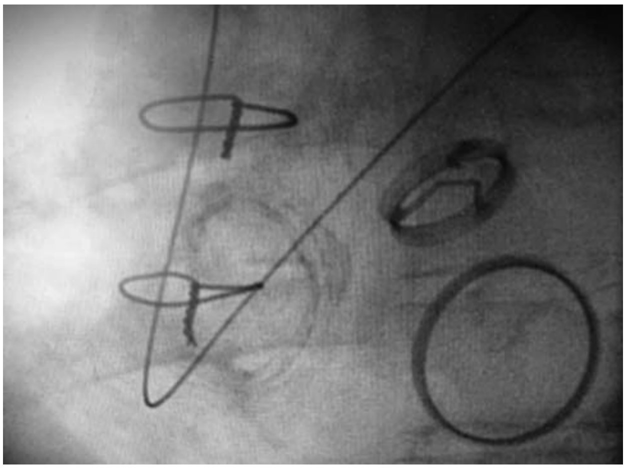

Fig. 1. A guidewire 0,035" is advanced to the right ventricle.

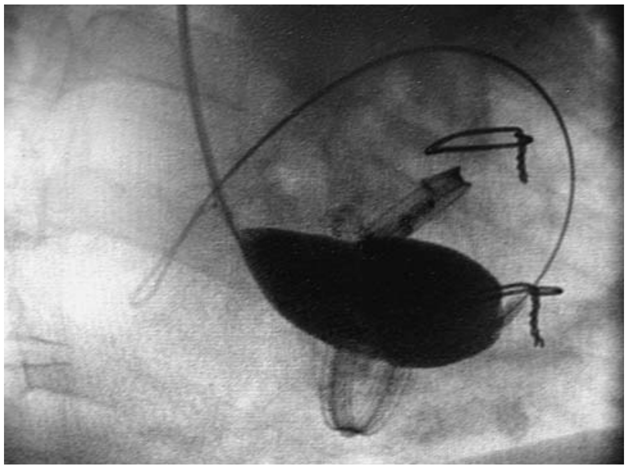

Fig. 2. Balloon valvuloplasty of tricuspid valve bioprosthesis.

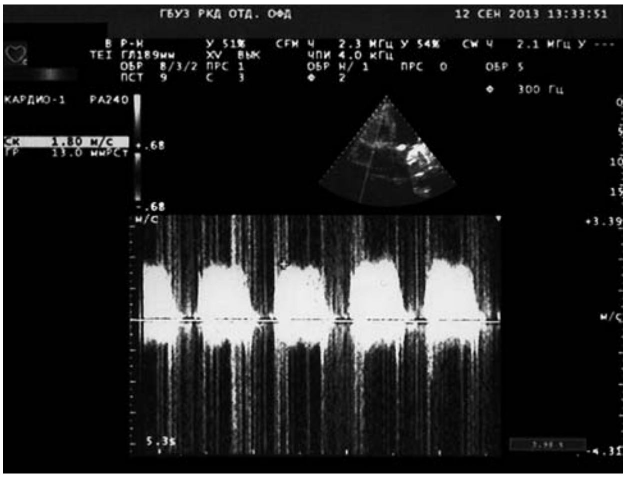

Fig. 3. EchoCG in 1 month after TBVP of tricuspid valve bioprosthesis.

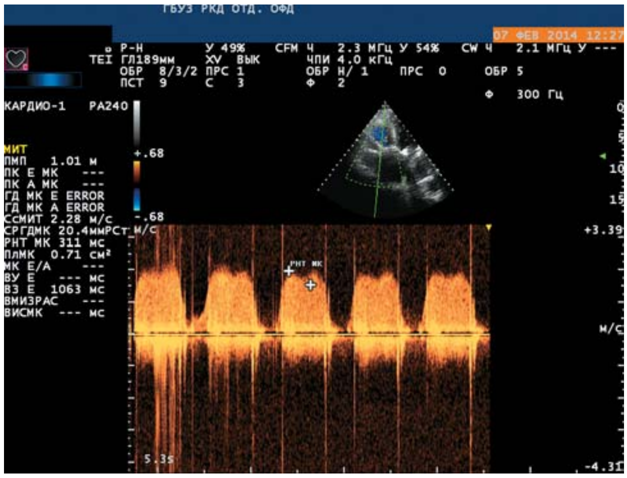

Fig. 4. EchoCG in 6 months after TBVP of tricuspid valve bioprosthesis.

pressure gradient from 22 to 14 mm Hg. The balloon was re-inflated at 1 atm., the tricuspid valve was dilated up to 19 mm in diameter with pressure gradient decreasing to 12 mm Hg; the Doppler orifice area increased to 1,2 cm^2 (Fig. 2). In view of significant decrease of pressure gradient and increase of orifice area, the procedure was stopped.

Control examination at day 2 after the procedure showed subjective improvement, a decrease of dyspnea and legs edema, an increase of physical tolerance, with transvalvular gradient persisting at the level of 12–13 mm Hg. At day 7, the patient was discharged in a satisfactory condition.

Control out-patient examination was carried out in 1 month. EchoCG showed decreased right atrial cavity (5,4 × 4,2 cm), transvalvular gradient 13 mm Hg (Fig. 3).

The next out-patient examination was conducted in 6 months. EchoCG revealed the signs of restenosis of tricuspid valve bioprosthesis: the pressure gradient increased to 22 mm Hg, the orifice area decreased to 0,7 cm^2 , while the right atrium size increased to 6,2 × 4,4 cm (Fig. 4). During the last month before the examination, the patient has noted a deterioration in his condition, with the recurrence of dyspnea and legs edema. Taking into account the increasing severity of heart failure, the patient was referred for surgical treatment.

Hence, balloon catheter valvuloplasty can be performed in patients with compromised history. It can improve intracardiac hemodynamics for a short period (un this case – for 6 months) and, if necessary, give the possibility to prepare the patient for surgical valve replacement.

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Results of Endovascular Interventions in Patients with Hibernating Myocardium

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Role and appropriateness of evaluation of myocardial vitality using dobutamine stress echocardiography in patients with post-infarction cardiosclerosis during planning of endovascular interventions are determined. It is shown that restoration of coronary blood flow in the areas of viable myocardium promotes fast and better restoration of kinetics of hibernating myocardium, that generally increases efficacy of percutaneous coronary interventions in this population and decreases rate of unjustified endovascular interventions. The correlation between durations of hibernation and restoration of the left ventricle local kinetics is determined.
Key words: *hibernating myocardium, myocardial vitality, percutaneous coronary interventions, post-infarction cardiosclerosis.*

Objective. To determine the role and prognostic value of myocardial vitality using dobutamine stress echocardiography as a part of complex treatment algorithm in patients with post-infarction cardiosclerosis, as well as efficacy and reasonability of endovascular interventions in this population.

Material and methods. 131 patients were enrolled according to inclusion/exclusion criteria. Time period between myocardial infarction and enrollment was from 3 to 18 months (on average, 8.5 ± 1.4 months). The patients were randomized into 2 arms using envelope method. In Arm I (n = 77), endovascular interventions in occluded arteries were performed based on stress tests and coronarography results. In Arm II (n = 54) myocardial vitality in areas of affected kinetics was determined, followed by endovascular interventions only in arteries supplying the area of viable myocardium. 12-month long-term results were obtained.

Results. During hospitalization and 12-month follow-up we observed no cardiovascular complications (death, MI, repeated intervention). Marked positive changes in myocardial kinetics after revascularization were observed. The number of segments with affected kinetics in Arm I decreased by 8.5% at Exam 2 and by 24.5% at Exam 3, while in Arm II the number of segments with affected systolic function decreased by 15.8% at the end of hospitalization and by 44.6% at the end of follow-up, i.e. almost twice compared to baseline data ($p < 0.0001$). Strong positive correlation ($r = 0.54$, $p < 0.05$) between time of blood flow restoration in viable myocardial areas and duration of its hibernation was revealed.

Conclusion. Endovascular restoration of coronary blood flow in patients with post-infarction cardiosclerosis and documented myocardial ischemia and presence of viable myocardium is a highly effective option both to reduce angina signs and prevent post-infarction remodeling of the heart and development of heart failure, thus positively influencing long-term prognosis of the disease.

Introduction

Delayed restoration of coronary blood flow in patients with acute coronary syndrome (ACS) leads to persistent changes in myocardial kinetics in the long term due to scar transformation. However, affected myocardial area is completely necrotized not in all patients who had myocardial infarction. The myocardium in this area quite frequently has mosaic structure in which necrotized myocardial zones are interleaved with zones of preserved general physiological functions but having no evidence of mechanic activity. These particular zones of viable but ischemic myocardium are predictors of long-term severe complications (1, 2).

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The conducted studies demonstrate that hibernating myocardium can die without timely restoration of perfusion in the ischemic areas while restoration of coronary blood flow in this population can result in improved quality of life and outcome. The regression of post-infarction changes in the heart confirmed by echocardiography proves this (2, 3, 4, 5).

The comparative meta-analysis of the late survival in patients with post-infarction cardiosclerosis (PICS) after surgical myocardial revascularization and those receiving only medical therapy, demonstrated that the mortality in patients with viable myocardium in post-infarction zone who underwent revascularization was lower than in patients receiving medications. In non-viable myocardium arm, the revascularization results were comparable with the results from medical therapy (6).

High survival of PICS patients with viable myocardium after surgical revascularization is related not only to reverse remodeling of the left ventricle but also to decreased incidence of fatal cardiovascular complications (7, 8). In this situation, medical therapy should not be considered as a separate treatment option in this population, but rather as an integral part of complex medical care for PICS patients (9).

The specificity and sensitivity of various methods to determine the viable myocardium are currently discussed. More attention is focused on dobutamine stress echocardiography, which is highly specific, safe for patients and cost-effective.

Dobutamine is a potent β_1-agonist, and its effect on α_1- и β_2-receptors is lower. At lower doses (5–10 µkg/kg/min), it is able to increase contractility of viable myocardium without significant increase in heart rate. However, at higher doses (20–40 µkg/kg/min), dobutamine imitates physical activity increasing heart rate and blood pressure; as a result, myocardial oxygen consumption increases. Biphasic response (increased systolic gain at lower doses and decreased myocardial contractility at higher doses of dobutamine) due to inconsistency between oxygen supply and demand makes it possible to classify dobutamine stress echocardiography as a specific method to determine the viable myocardium (10).

Comparison between dobutamine stress echocardiography results and perfusion scintigraphy results in patients after successful myocardial revascularization demonstrates similar sensitivity of stress echocardiography (74–94%) and scintigraphy (89–100%). However, specificity of radionuclide methods is lower (40–55%) compared to stress echocardiography (77–95%) (11,12).

Positron-emission tomography (PET) with ^{18}F-deoxyglucose giving information on glucose metabolism in hypoperfused myocardial area is considered to be the “gold standard” for assessment of viable myocardium (13). However, PET application in national practice is limited for economical reasons.

Although dobutamine stress echocardiography has been studied worldwide since 1990s, it remains unclaimed in real clinical practice of the majority of Russian healthcare institutions for unknown reasons, and PICS patients are referred for myocardial revascularization based on coronarography results only, while viability of the myocardium is not determined.

Therefore, the objective of this study was to determine the role and prognostic value of myocardial viability assessed with dobutamine stress echocardiography as a part of complex treatment algorithm for PICS patients, as well as the efficacy and reasonability of endovascular interventions performed in this population.

Material and methods

147 PICS patients were enrolled in the prospective study conducted from January 2012 till May 2014 at the Center of Cardiovascular Pathology of the Non-State Healthcare Institution N.A. Semashko Central Clinical Hospital No 2 of Russian Railways Public Corporation.

The study was approved by the Local Ethics Committee at N.A. Semashko Central Clinical Hospital No 2 of Russian Railways Public Corporation.

Inclusion criteria: functional class II–III angina pectoris according to CCS (Canadian Cardiovascular Society) classification; documented myocardial ischemia (based on the stress tests results); occlusion or subtotal stenosis of one or several coronary arteries confirmed by digital angiography; left ventricle segments with impaired myocardial contractility; signed patient’s information consent for participation in the study.

Exclusion criteria: acute coronary syndrome; FC IV angina at randomization; technically impossible endovascular intervention; multivessel coronary disease with SYNTAX score ⩾32; another chronic disease which may affect the immediate prognosis; patient’s refusal from the study participation.

131 patients were enrolled per Protocol criteria.

Time period between infarction onset and enrollment ranged from 3 up to 18 months (on average, 8.5 ± 1.4 months).

At selection, all patients underwent coronary angiography, cycle ergometry, transthoracic echocardiography at rest.

The patients were randomized into two arms using envelop method. In Arm I (n = 77), endovascular interventions for occluded arteries were performed based on stress tests and coronarography results. In Arm II (n = 54), the myocardial viability in zones of affected kinetics was determined, followed by endovascular interventions limited only to arteries supplying zone of viable myocardium.

To assess myocardial viability and dynamics of local kinetics changes in post-operative period, dobutamine stress echocardiography was performed in accordance with the standard protocol including determination of systolic myocardial thickness gain in the areas of affected local contractility at lower doses of dobutamine as well as worsening of existing and/or development of new changes in regional contractility at higher doses (14, 15).

Dobutamine (HEXAL, Germany) was administered using infusion pump each 3 minutes at doses of 5, 10, 20, 40 mg/kg/min. At HR less than 85% of age limit and lack of criteria for test interruption, 0.5 mg of atropine was administered intravenously every 2 minutes after maximum dose of dobutamine till interruption criteria are met (maximum up to 2 mg of atropine depending on patient's body weight).

Echocardiographic images were recorded at baseline at rest and at the end of every step in four main positions: parasternal left ventricle by long and shot axes, apical four-chamber and apical two-chamber ones.

ECG was recorded during the whole test and blood pressure was measured at every step of stress test.

The test was stopped when the following occurred: submaximum physical (electrophysiological) exercise load was achieved, maximum dose of the pharmacological agent was administered, signs of affected local contractility appeared in the segments with unchanged kinetics at baseline, contractility worsened in segments already affected at baseline, there were observed onset of angina or its equivalents, asthma attack or significant shortness of breath, ischemic changes on ECG, onset of life-threatening cardiac arrhythmias and conduction disorders (frequent polytopic, group, early premature ventricular contractions, paroxysmal rhythm disorders), or systolic and diastolic blood pressures exceeded 230 mmHg and 130 mmHg respectively.

The results were assessed by simultaneous display and comparison of four echocardiographic images corresponding to each exercise step. The local contractility was assessed using 4-point scale of 16-segment model calculating index of affected regional contractility. The index was calculated as ratio of the sums of affected local contractility points for every segment of the left ventricle and number of analyzed segments: normokinesis – 1 point; hypokinesis – 2 points, akinesis – 3 points, dyskinesis – 4 points.

The viable segments were determined as those with increased local contractility by 1 point and more. The test was considered to be negative if there was no increase in systolic myocardial thickness at lower doses of dobutamine (5, 10 mg/kg/min) or decrease in myocardial contractility at higher doses (20, 40 mg/kg/min).

The arms were comparable by clinical and demographic data and angiographic parameters (Tables 1, 2).

Endovascular interventions were performed using digital angiographic equipment Innova 3100IQ, General Electric. Zones with affected local kinetics were visualized using Vivid 3, General Electric.

Angiographic criteria of stenting success were as follows: blood flow TIMI III, residual stenosis <30%, no evidence of type D-F dissection according to NHBLI classification.

In all patients, optimal medical therapy for CHD was selected (angiotensin-converting enzyme inhibitors, beta-blockers, statins, disaggregants: clopidogrel (Plavix) 75 mg OD, acetylsalicylic acid). The patients took disaggregants for 12 months after endovascular intervention.

The changes in local contractility were evaluated prior to percutaneous coronary intervention (Exam 1), before discharge from the hospital (Exam 2) and 12 months after intervention (Exam 3).

The immediate results of the study were assessed using the following criteria: survival, incidence of adverse cardiovascular complications (death, MI, urgent repeated interventions), regress of angina manifestations by 2 and more FCs, increase in physical tolerance, change in local kinetics of the myocardium.

The long-term results were assessed using the following criteria: survival, incidence of adverse cardiovascular complications (death, MI, repeated interventions), incidence

Table 1. Clinical and demographic characteristics of patients

Parameter	Arm I (n = 77)		Arm II (n = 54)	
	abs.	%	abs.	%
Men	52	67.5	40	74
Women	25	32.5	14	26
Mean age	58.4 ± 9.8		61.3 ± 10.1	
Mean duration of PICS, months	7.7 ± 3.3		8.1 ± 3.1	
FC 2 angina	41	53.2	32	59.3
FC 3 angina	36	46.8	22	40.7
Essential arterial hypertension	58	75.3	39	75
Diabetes mellitus type 2:	18	23.4	14	25.9
I FC	15	19.5	10	18.5
II FC	38	49.4	29	53.7
III FC	24	31.1	15	27.8
Smoking	28	36.3	30	55.6

* $p > 0.05$.

Table 2. Angiographic parameters in patients

Lesion type	Arm I (n = 77)		Arm II (n=54)		p
	abs.	%	abs.	%	
One- and two-vessel lesion	26	33.7	16	29.6	
Three-vessel lesion	28	36.4	23	42.6	
Bifurcation stenoses	18	23.4	12	22.2	>0.05
Ostial stenosis	5	6.5	3	5.6	
Anatomical characteristics					
LAD stenosis	36	46.7	26	48.1	
CA stenosis	21	27.3	14	25.9	>0.05
RCA stenosis	20	26	14	25.9	

LAD – left anterior descending artery, CA – circumflex artery, RCA – right coronary artery.

of restenosis and in-stent thrombosis, change in local kinetics of the myocardium.

The statistical analysis of the results was performed using MS Statistica 7.0 software package. Pearson test was used for association analysis; for estimating significance of differences between two arms t-test was used. F-test and Newman-Keuls test were used for multiple comparisons.

Results

All patients were implanted with drug-eluting stents. A total of 194 stents were implanted (mean number of stents per patient is 1.57 ± ± 0.69). In Arm I, 141 stents were implanted (mean number of stents per patient is 1.8 ± 0.02), in Arm II, 67 stents were implanted (mean number of stents per patient is 1.3 ± 0.16) ($p < 0.05$).

Endovascular intervention was successful in 91.6% and 96.2% of patients, respectively. In 8 patients endovascular intervention was not technically possible to be performed, therefore, these patients were withdrawn from the study. Thus, 123 patients further participated in the study (71 patients in Arm I and 52 patients in Arm II).

All the enrolled patients demonstrated clinical improvement, i.e. decreased angina functional class and increased physical exercise tolerance (Table 3), already by the end of hospitalization.

12-month long-term results were obtained in all patients.

During hospitalization and 12-month follow-up we observed no cardiovascular complications (death, MI, repeated interventions).

At the final visit (Exam 3), coronarography was performed in 6 patients due to recurrence of angina, 4 patients (5.6%) out of them were from Arm I and 2 patients (3.8%) from Arm II ($p < 0.05$). Given the small number of patients with relapsed angina, the long-term results were further assessed for all enrolled patients not dividing them into the appropriate arms.

Based on coronarography data, the reason for angina recurrence in 3 patients was progression of atherosclerosis in other segments of previously stented arteries, which required

Table 3. Immediate study results

Physical exercise tolerance (n = 123)					
Level, MET			Performed exercise (W)		
Exam 1	Exam 2	Exam 3	Exam 1	Exam 2	Exam 3
4.01 ± 1.6	6.76 ± 0.24*	6.65 ± 0.3*	62.4 ± 4.4	138.3 ± 2.1*	136.7 ± 3.2*

Dynamics of angina regress

Angina class	Exam 1		Exam 2*		Exam 3**	
	Arm I (n = 71)	Arm II (n = 52)	Arm I (n = 71)	Arm II (n = 52)	Arm I (n = 71)	Arm II (n = 52)
0	0	0	45	38	43	38
I	0	0	22	12	20	10
II	39	32	4	2	6	4
III	32	20	0	0	2	0

*$p < 0.001$ compared to Exam 1. **$p < 0.001$ compared to Exam 1.

Table 4. Dynamics of affected local myocardial contractility of the left ventricle

Показатель	Exam 1		Exam 2		Exam 3	
	Arm I	Arm II	Arm I	Arm II	Arm I	Arm II
Total number of assessed segments	1136	832	1136	832	1136	832
Segments with normal kinetics	667	531	858	651	907	714
Affected segments, total	469	301	278	181	229	118
Out of them:						
hypokinetic	327	206	182	107	116	41
akinetic	127	90	64	42	51	23
dyskinetic	15	5	9	3	6	2

repeat intervention; in 2 other patients the reason for recurrence was late in-stent thrombosis related to replacement of original disaggregants with generics, this also required repeat intervention. 1 out of 6 patients had repeat intervention in the segment of the previously stented artery due to in-stent restenosis.

Therefore, the rates of repeat interventions on stented (target) vessel (target vessel revascularization – TVR) and previously stented arterial segment (target lesion revascularization – TLR) in all enrolled patients were 2.4% each. Although, rate of in-stent thrombosis unrelated to fatal MI was 1.6%.

Based on transthoracic echocardiography performed before intervention, a total of 1136 myocardial segments were evaluated, 770 out of them had affected kinetics at baseline. In Arms I and II, the kinetics was affected at baseline in 469 and 301 segments, respectively (Table 4).

As evident from the presented data, dynamics of restoration of the local kinetics was more significant in Arm II: the number of segments with affected kinetics in Arm I decreased by 8.5% at Exam 2 and by 24.5% at Exam 3, while in Arm II the number of segments with affected systolic function decreased by 15.8% at the end of hospitalization and by 44.6% at the end of follow-up, i.e. almost twice compared to baseline data ($p < 0.0001$). However, the numbers of both hypokinetic and akinetic segments decreased.

Such changes can be explained by that fact that in Arm II the patients with viable myocardium in the hibernating zone were initially selected, while Arm I might include patients with both viable myocardium and irreversible changes in kinetics; this once more confirms the efficacy of blood flow restoration in zone of viable myocardium.

In our study, strong positive correlation ($r = 0.54$, $p < 0.05$) was observed between time period of blood flow restoration in zone of viable myocardium and duration of its hibernation (Figure 1). In particular, patients who had myocardial infarction less than 6 months prior to enrollment demonstrated positive changes at discharge while patients with PICS prolonged more than 6 months needed approximately 1 year to restore maximally the function of previously hibernating myocardium.

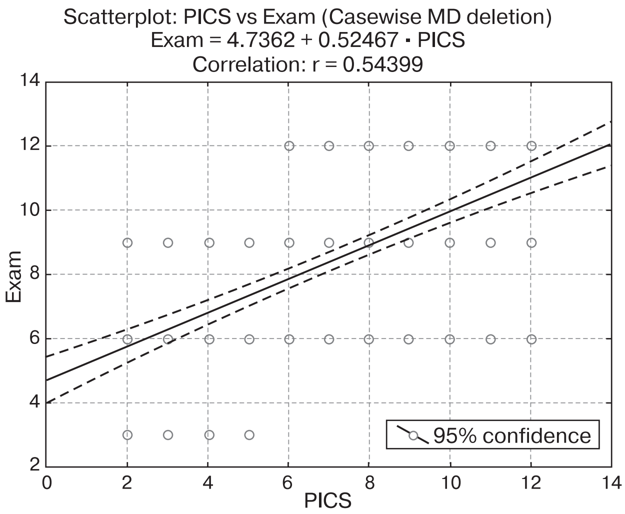

Figure 1. Correlation analysis between time period for blood flow restoration in areas of viable myocardium and duration of its hibernation

Conclusion

Therefore, endovascular restoration of coronary blood flow in patients with post-infarction cardiosclerosis, documented myocardial ischemia and viable myocardium is a highly effective method both to reduce angina manifestation and to prevent post-infarction remodeling of the heart, development of heart failure, thus positively influencing long-term prognosis of the disease. The preoperative evaluation of myocardial viability using stress echocardiography may be considered as one of the principle criteria for successful endovascular treatment of PICS patients and should be included in the protocol of preoperative preparation of all PICS patients in order to prevent unreasonable coronary interventions and increase the efficacy of percutaneous coronary interventions in this population.

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Optical Coherence Tomography for Evaluation of Coronary Stents

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To date, angiographic visualization of the vessel's contours is the "gold standard" in the evaluation of vascular wall condition, in native, as well as in stented segments. However the evaluation of endothelialization degree in the lumen of a stented segment often is not complete due to two-dimensional radiological presentation. The existing methods of intravascular visualization, especially optical coherent tomography, permit to assess the stented segment with maximal accuracy and reliability. This study was aimed at the evaluation of the possibilities of optical coherent tomography in the examination of coronary stents' condition in the mid-term after implantation.

Key words: *intravascular visualization, optical coherent tomography, coronary stenting.*

To date, endovascular methods of diagnostics and treatment in cardiology have great advantages in both correction of technically complex lesions and highly accurate morphological intravascular diagnostics. Angiography is the "gold standard" of vessel visualization in interventional cardiology. However, this method is limited with two-dimension presentation of lumen shadow and not always provides accurate information on coronary angioplasty and stenting results (1). Intravascular ultrasound (IVUS) and optical coherence tomography (OCT) maintain the leadership positions among the most spread methods of intravascular visualization. Although both these methods are used in interventional cardiology for the same purpose, each of them has some fundamental limitations precluding from their interchangeable use.

IVUS limitations are as follows: small vessel diameter (<2.25 mm), distal lesion, vessel tortuosity as well as altered venous graft. The significant disadvantages of this method are: poor visualization of intimal structure and intraluminal thrombi (thrombi, floating dissections), fibrous capsule of atherosclerotic plaque, failure to evaluate the nature of in-stent neointimal proliferation. The prolonged accumulation of experience for adequate interpretation of obtained images is also a considerable limitation (2, 3). Nevertheless, IVUS is a viable visualization method which does not require additional administration of the contrast medium (which is topical for patients with kidney disorders), and also it is more precise in those areas where the adequate optical density cannot be obtained due to turbulent flux and fast blood flow (orifices of the left main coronary artery and right coronary artery (RCA)) (4). Physical aspects and limitations of the methods are presented in Table 1.

In physics, light coherence is coherence of a few light waves in time manifesting during their interference. OCT effect is based on measuring the time of delay of a light beam reflected from the tissue under study. Intravascular OCT requires a single fiber optic cable which radiates light and records data. Broadband extra bright light-emitting diode "highlights" surrounding tissues, and central processor measures delay time of signal reflected from the tissue and processes it using complex mathematical algorithm. This coordination between several light waves coming from the transducer onto the tissues and reflected from the tissues onto a control mirror of optical fiber is physical light interference.

Using this wavelength, depth of penetration into the tissues is limited from 1 to 3 mm (compared to 4–8 mm for intravascular ultrasound), with the maximum diameter of view up to 6.8 mm. OCT may be performed in vessels ranging from 2.0 to 3.75 mm in diameter (1, 5).

As the object of study is the possibility to accurately and adequately assess proliferation in stented segments of coronary arteries, the special attention should be paid to the study performed by Gutierrez H. et al. who evaluated

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Table 1. Physical aspects and limitations of the methods

	IVUS	OCT
Frames per second, fps	30	100–200
Transducer diameter, mm	0.7	0.4
Speed of traction, mm/sec	1	20–40
Wave length, µm	35–80	1.3
Axial resolution, µm	150	10–15
Lateral resolution, µm	250	40–90
Depth of penetration, mm	7	2–3
The size of catheter, mm	1	0.8
Administration of the medium	–	+

Table 2. Clinical and historical characteristics of the patients

	Xience V, n = 21	MLV, n = 28	Significance of difference
Age, years	60 ± 9,9	59 ± 9,1	$p > 0.05$
Smoking, n (%)	10 (41)	13 (48)	$p > 0.05$
Essential hypertension, n (%)	17 (74)	24 (79)	$p > 0.05$
Cholesterol >5 mM, n (%)	10 (41)	9 (36)	$p > 0.05$
Triglycerides >1.7 mM, n (%)	8 (32)	8 (33)	$p > 0.05$
Diabetes mellitus, n (%)	4 (15)	6 (17)	$p > 0.05$

the stenting results from 6 patients with optimal angiography outcomes. The OCT images revealed a thin cap of fibroatheroma, tissue prolapsed through the stent cells, incomplete stent adjoining with vessel wall and thrombus around the catheter. As a result, OCT revealed a zone of suboptimal PCI results in contrast to optimal angiographic image (6).

Yao Z.H. et al. observed 6-month complete endothelialization in 18% of patients only (8 out of 42) based on OCT data. Moreover, tissue thickness increased from Month 6 till Month 12 (from 42 ± 28 µm to 88 ± 32 µm) (7). Other OCT studies demonstrated that 81% of patients had incompletely endothelialized struts 2 years after DES implantation. The struts without visible tissue illumination were frequently observed in bifurcation and stent overlapping cases (8).

Given variable literature data, modernity, but low prevalence of OCT in clinical practice and limited assessment of proliferation morphology in stented segments in vivo, we considered the following study to be topical in our clinical practice.

The study objective was to determine the potential of optical coherence tomography to assess coronary stents 6 months after implantation. 61 coronary stents were implanted in 49 patients enrolled in the study at the State-Funded Healthcare Institution Moscow City Centre of Interventional Cardioangiology, Moscow Healthcare Department from September till February 2012. The study included patients with new-onset stable angina and angiographycally confirmed one coronary stenosis ⩾75%. The patients with recanalized chronic occlusions, or calcified stenosis, or acute coronary syndrome, or kidney disease in whom volume of injected contrast media was strictly limited were excluded. Patients were divided into two arms as follows: with implanted Xience V vs. Multi-link vision (MLV) stents. Clinical and historical characteristics of the patients are presented in Table 2.

The stents were implanted under angiography guidance (no intravascular visualization) using at least nominal pressure recommended by the manufacturer. The angiographically successful implantation was considered to be full deployment and adequate stent positioning, no residual stenosis or evidence of dissection.

Angiographically successful implantation was achieved in 49 patients (100%). In Xience V arm, 17 patients were implanted with 1 stent each, 3 patients were implanted with 2 stents each and 2 patients were implanted 3 stents each. 4 stents were overlapped. In MLV arm, 23 patients were implanted with 1 stent each, 4 patients were implanted with 2 stents each and 1 patient was implanted with 3 stents. 2 stents were overlapped. Out of 6 overlapped implanted stents, 3 ones were implanted for dissection and 3 – for incomplete plaque coverage.

In both arms the majority of stents were 3.0 × 15–23 mm. As the large arteries are difficult to fill adequately with contrast media, we included in the study no patients who were implanted with stents ⩾4.0 mm in diameter. The

Table 3. Diameters of the implanted stents

Diameter, mm	Xience V, n = 29	MLV, n=34
2.5	4	6
2.75	7	5
3.0	11	14
3.5	7	9

Table 4. Lengths of the implanted stents

Length, mm	Xience V, n = 29	MLV, n=34
⩽15	11	10
15–23	12	15
⩾ 23	7	9

Table 5. 6-month stenting results based on coronary angiography and OCT data

	Xience V, n = 29	MLV, n = 34
Satisfactory result (angiographic)	27 (93%)	29 (85%)
Complete endothelialization	18 (62%)	27 (79%)
Restenosis (?70%)	1 (3.5%)	3 (8.8%)
Incomplete plaque coverage	1 (3.5%)	–
Incomplete stent deployment	3 (10.3%)	2 (5.8%)
In-stent thrombosis	–	2 (5.8%)
Repeated intervention (in-stent PTCA)	1 (3.5%)	6 (17.6%)*

* in one case, struts of two stents incompletely adjoined at the edges.

data on dimensions of the used stents are presented in Tables 3 and 4.

All patients were prescribed with standard commonly recognized dual antiplatelet therapy (aspirin + clopidogrel).

All 49 patients underwent control coronary angiography followed by OCT irrespective of stent angiographic status. The mean follow-up was 5.7 ± 1.2 months in Xience V arm and 6.1 ± 1.4 months in Multi-link vision arm. Before follow-up examination, 47 out of 49 patients complied with dual regimen “aspirin + clopidogrel”. 2 patients were admitted with AMI on Day 25 and Day 72 after implantation.

Control CAG and OCT were performed in routine manner. Mean fluoroscopy time was 10.2 ± 1.7 min. Mean contrast media consumption was 180 ± 65 mL. OCT was performed using equipment LightLab St. Jude medical C7 x R and catheters C7 Dragonfly. Intracoronary contrast medium (Omnipaque 350) was injected using automatic injector as follows: left coronary artery – 20 mL with a rate of 5 mL/sec; right coronary artery – 15 mL with a rate of 3 mL/sec. Adequate and simply interpretable images were obtained in all cases. Lumen loss in stented segments was calculated in 3 locations: proximal and distal edges of the stent and an area with maximum in-stent lumen loss.

The angiographically satisfactory result was achieved in the vast majority of cases; OCT revealed complete endothelialization in 62% of stents in Xience V arm and 79% stents in MLV arm. Angiographically determined restenoses in Xience V and MLV arms were also confirmed with calculated OCT data. It should be noted that there were no inconsistencies between OCT and angiography data, i.e. no hemodynamically significant restenoses invisible angiographically but observed at OCT. In 5 cases of angiographically satisfactory result, OCT revealed incomplete stent deployment. Stent thrombosis was observed in 2 cases in MLV arm (see Table 5).

Figure 1 shows OCT image from the patient with MLV stent, who voluntarily interrupted antiplatelet therapy on Day 25. The stent struts not covered with neointima and fragments of white thrombus rich in platelets and fibrin are easily differentiated on this image due to homogenous scattering of reflected light and low speed of scattering.

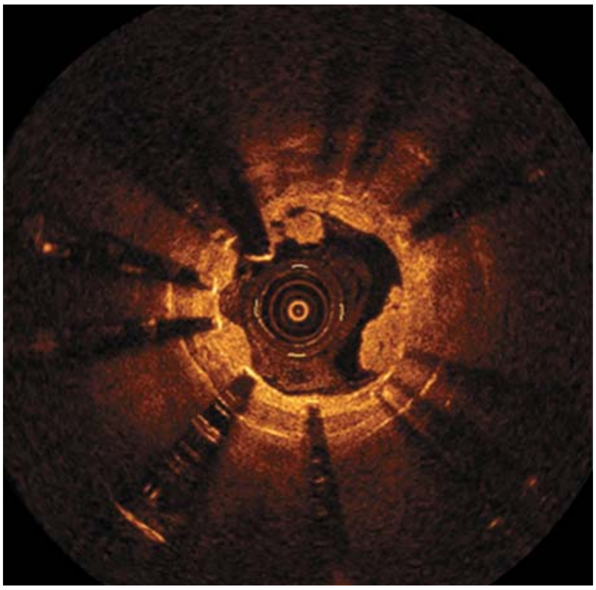

Figure 1. Fibrin-containing white thrombus in stented segment (see description in the text).

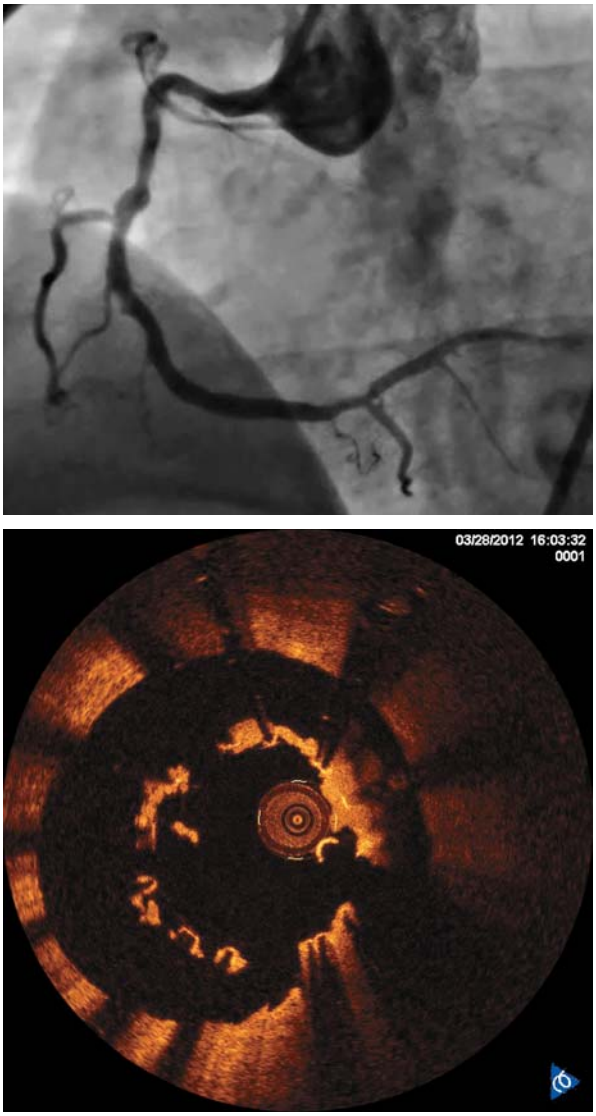

Figure 2. Control CAG and OCT in the stented segment of the right coronary artery (see description in the text).

Figure 3. Optical tomogram of overlapped stents.

Figure 2 presents angiographically satisfactory result of stenting of the medium part (MLV 3.0 × 23) of RCA based on control coronary angiography (left side) and incomplete stent deployment with thrombus fragments based on OCT data (right side) in the same segment. Balloon angioplasty was successfully performed.

One more interesting, in our opinion, OCT image was obtained from the patient implanted with 2 edge-overlapping stents (overlapping method). The image presents tomography view of overlapped stents with complete endothelialization of the stent struts. It should be noted that the struts of both stents are “fitted” into the vessel wall at different depths (Fig. 3).

To date, optical coherence tomography is a key method of intracoronary visualization able to overcome some limitations related to angiography and intravascular ultrasound. Highest axial definition, similar to histological examination, provides microstructural information on healing of implanted stents *in vivo*. Many clinical studies demonstrated OCT potential to identify incomplete stent adjoining after implantation, reliably visualize neointimal hyperplasia on stent struts and many other structures.

Therefore, OCT is a modern high-definition method of intravascular visualization to assess coronary vessels wall inside the stented segments with higher reliability and speed. OCT helps to more accurately monitor prescription and intake of disaggregants via scanning of non-endothelialized parts of stent, that may provide more definitive answers to questions on timing of these drugs intake in future. Due to its high definition, this method is virtually a native coronary microscope permitting to monitor post-implantation healing physiology and pathomorphology with high precision. Routine OCT-guided stent implantation helps to avoid such technical errors as incomplete plaque coverage and incomplete adherence of stent struts to vessel wall and to determine angiographically indistinguishable dissections. Obviously, development of intravascular visualization methods requires comprehensive anatomical and histological justification of coronary endovascular interventions.

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Strategy of Coronary Artery Bypass Grafting for Arteries with Moderate (<75%) Stenosis being a Part of Multivessel Disease during Direct Myocardial Revascularization

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So far, there is no clear strategy for revascularization of CAs with non-critical (<75%) lesions being a part of multivessel disease during direct myocardial revascularization. There are no clinically and angiographically proven results indicating which minimal CA stenosis is reasonable for using ITA to ensure longevity typical for this conduit. The study is based on retrospective (on average, 6.4 ± 1.8 mo) analysis of preoperative and long-term CAG postoperative data obtained from 567 patients. The patients are divided depending on stenosis degree and conduit type. The superiority of venous conduits over ITA for revascularization of CAs with single stenosis ⩽ 70% is proven. The revascularization strategy for critical proximal stenosis in one vessel combined with no significant stenosis between this vessel and another vessel from the same arterial territory is determined.

Key words: *myocardial revascularization, mammary artery, venous graft, non-critical stenosis, long-term coronaroangiography, competitive blood flow, graft reduction, myocardial revascularization strategy.*

Direct myocardial revascularization is a treatment of choice (IA class according to EAK classification, 2010) for coronary heart disease (CHD) involving multivessel disease of coronary arteries (CAs) (1, 2), LMCA lesions (1, 3, 4), diabetes (5, 6), and some other cases (7, 8). Further improvement of direct revascularization results is impossible without clear understanding of strategic errors. For this purpose, the comprehensive analysis of reasons for graft failure should be performed in each specific case.

Although there are many reports on superiority of arterial conduits over venous ones in modern literature, complete arterial revascularization is performed in 3–4% of cases only (9). Clinical experimental studies of long-term results indicate large dependency of functional status of arterial conduits on CA stenosis degree (10).

Absolute fatuity of using the radial artery (RA) and gastroepiploic artery (GEA) in CA stenosis <85% has been currently proven (23, 24). In such cases, they become spastic in early postoperative period, with normal function arrest and occlusion (25).

There is no clear opinion which minimal CA stenosis is reasonable for using ITA to ensure longevity typical for this conduit. Some authors propose to use ITA for CABG if CAs have even moderate (50–70%) stenoses with the purpose to prevent myocardial ischemia if stenosis degree further increases (27). Other studies (10, 11) report that ITA alike other arterial conduits may be spastic and occluded if CABG is used for CAs with non-critical lesions.

So far, in the literature there is no clear definition of revascularization strategy for two or more vessels of the same arterial territory with different stenosis degrees (critical and non-critical). Based on the mentioned above, we decided to evaluate the comparative functional long-term adequacy of ITA and GSV in revascularization of vessels with <75% stenoses being a part of miltivessel disease to clarify surgical strategy and optimize CABG results.

The study is based on retrospective analysis of preoperative and long-term postoperative CAG data depending on stenosis degree and conduit type.

Material and methods

As of December 31, 2013, more than 1500 direct myocardial revascularization surgeries were performed in the Cardiosurgery Depart-

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Table 1. Graft status after revascularization of coronary arteries with stenosis <75%

Function	Total	+	–
Artery	78 (70,9%)	45 (57,7%)	33 (42,3%)
Vein	32 (29,1%)	28 (87,5%)	4 (12,5%)
Total	110 (100%)	73 (66,4%)	37 (33,6%)

Table 2. Results of impact of additional stenosis in non-critical stenosed vessel on conduit functional competence

Anatomy	Function	+	–
+ LMCA	33 (42,3%)	29 (87,8%)	4 (12,1%)
+ "bad" vessel	8 (10,3%)	7 (87,5%)	1 (12,5%)
Isolated stenosis	37 (47,4%)	9 (26,7%)	28 (75,7%)
Total	78 (100%)	45 (57,7%)	33 (42,3%)

ment. Mean mortality rate was 1.4 ± 0.3%. All surgeries were performed using cardiopulmonary bypass and Custodiol cardioplegia modified in our Centre. Mean number of grafts per patient was 2.92 ± 0.7, at least 1 ITA was used in 96% of cases. GSV was mainly used as the second graft (99%).

The coronary artery status was assessed based on quantitative CAG analysis. The indication for revascularization was stenosis ⩾ 70% determined by CAG.

All patients regardless of their clinical status were offered follow-up CAG 6 months after surgery. Therefore, 567 patients were examined within the period from 6 months till 9.5 years after surgery (on average, 6.4 ± 1.8 mo).

Definitions. Stenosis <75% was considered to be non-critical. The graft function was considered to be satisfactory if the graft and coronary artery were filled antegradely, with no stenosis ⩾ 70% in any part of the whole conduit. The following situations were considered to be unsatisfactory: 1) graft occlusion with no antegrade blood flow, 2) significant stenosis ⩾70% in any part of graft body and/or at the any end of anastomosis, or 3) so called String Sign (selective CAG visualizes ITA along the whole length but its diameter is less than 1 mm).

Given anatomical and physiological differences between ITA and GSV, the patients were divided by graft type (arterial or venous), functional status, and stenosis degree (>75% and <75%) into two arms each.

Non-critical stenoses in revascularized CAs were revealed in 110 patients (19.4%). As the nature of our study is to evaluate the status after each performed shunt, the calculations were based on the number of actual anastomoses. Therefore, 567 patients had 1544 revascularized vessels. Correspondingly, the portion of non-critical stenoses was 7.1%. ITA and great saphenous vein (GSV) were used in 78 cases (70.9%) and 32 (29.1%) cases, respectively.

Repeat CAG revealed satisfactory function of the grafts in 84.9% out of 1544 performed anastomoses. At the same time, when the vessels with non-critical stenoses were revascularized, the grafts had normal function in 66.4% of cases only (73 patients) ($p < 0.05$) (Table 1). The significant difference should be noted in competency between arterial and venous grafts (Table 2). Namely, in the overall population and this specific population, ITA adequate function was observed in 86.7% and only 57.7% of cases (45 grafts, $p > 0.01$), respectively. But the venous grafts had normal function in 87.5% of cases (28 grafts). In overall population, the rate of GSV normal function was almost similar (82.8%).

The analysis of reasons for ITA graft competency demonstrated (Table 2) that 36 (80%) conduits out of 45 normal mammary conduits had additional stenoses located more proximally to the "main" stenosis. However, combined stenosis (>60%) of the left main coronary artery was observed in 29 (64.4%) patients, and additional prolonged (>1.5 cm) stenosis (50–60%) of the same coronary artery was noted in 7 cases (15.6%). The rates of occlusion and String Sign of mammary grafts were 63.6% (21 grafts) and 36.4% (12 grafts), respectively. The mammary grafts had normal function in 9 cases (26.7%) only in the isolated non-critically stenosed vessels (37 patients). It should be considered as a true impact of non-critical stenosis on long-term ITA competence.

The assessments of venous grafts in revascularization of CAs with moderate stenosis revealed an opposite pattern. Regardless of revascularization area, 28 (87.5%) out of 32 grafts had normal function. Graft occlusion was observed in 4 cases (12.5%). Notably, repeated

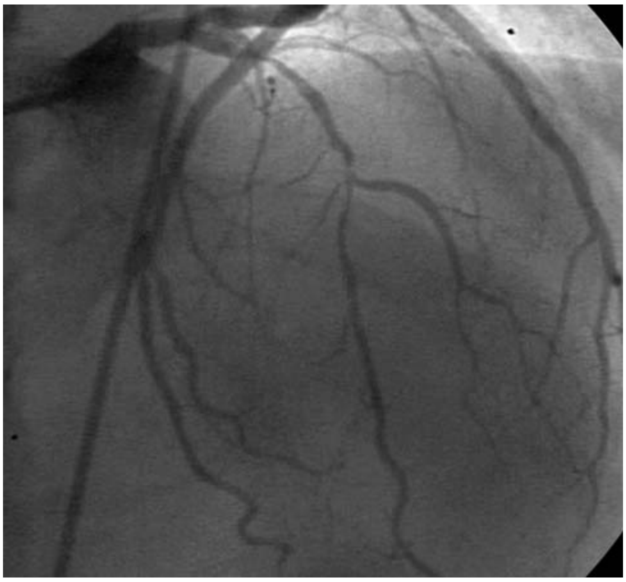

Figure 1. Patient A. LAD critical stenosis above DA orifice. There is no significant stenosis between two arteries. LAD is revascularized using LITA *in situ*, DA is revascularized using autologous vein.

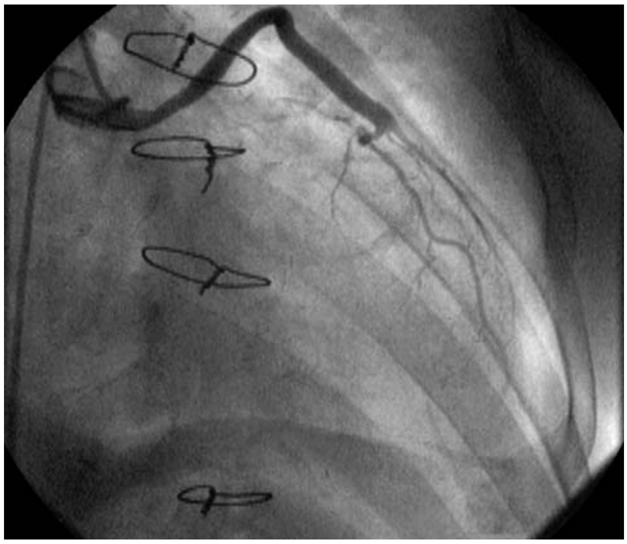

Figure 2. Patient A. 6-month follow-up CAG: There are no clinical signs of angina. It is revealed: satisfactory function of the venous graft to DA and blood reflux in

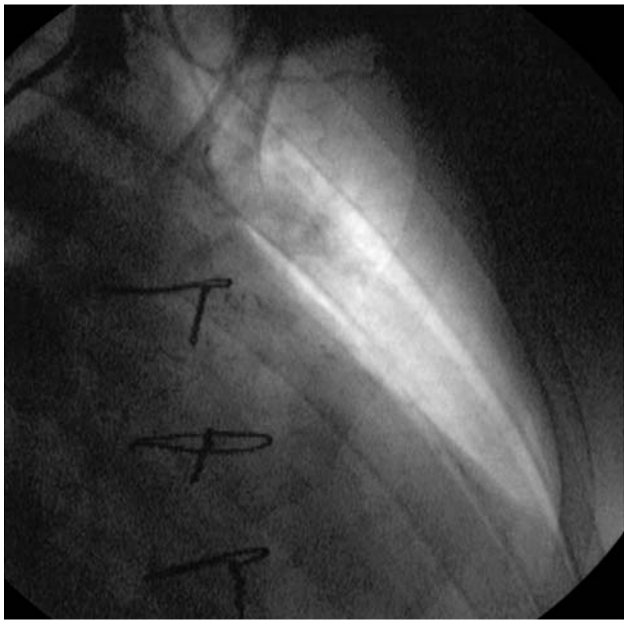

Figure 3. Patient A. *In situ* LITA to LAD is occluded.

CAG revealed that stenosis decreased (or was like this at baseline) and became <60%, with CA diameter more than 2 mm.

There should be separately reviewed 5 cases of iatrogenic ITA-competitive blood flow due to venous graft when the neighbouring vessel of the same arterial territory was grafted. As a result, mammary grafts were reduced and occluded. In 3 cases, DA with proximal stenosis <70% was grafted using GSV and LAD with critical stenosis above the DA origin was grafted using ITA. In another case (LMCA stenosis 85%), intermediate coronary artery was grafted using mammary artery and OMB (proximal stenosis up to 70%) was grafted using the vein. In another case (LCX with orifice critical stenosis), the first MA was grafted with ITA and the second one with the venous conduit. In all cases, venous conduits had normal function and ITAs were occluded.

Special attention should be paid to 2 cases when the first follow-up CAG performed 6 months after surgery reveled String Sign of ITA to LAD; therefore, these patients were re-examined 7 months later. In both cases, LAD stenosis increased (up to 80% and 85%, respectively) and function of mammary grafts became satisfactory.

These examples clearly confirmed the opinion that stenosis degree and, as a consequence, the volume of blood flow through the native artery (under other equal conditions) determines functional status of the arterial graft.

Discussion

The primary advantage of direct myocardial revascularization is long-term positive results (12, 13).

There are no doubts that further improvement of efficacy related to direct myocardial revascularization will mainly depend on the correct choice of surgical approach. Any other approach will discredit this method, and, most importantly, will not lead to desirable effect for a patient.

Assuming that all vessels with >70% stenosis should be grafted, then this law seems not always applicable for arterial grafts. Absolute

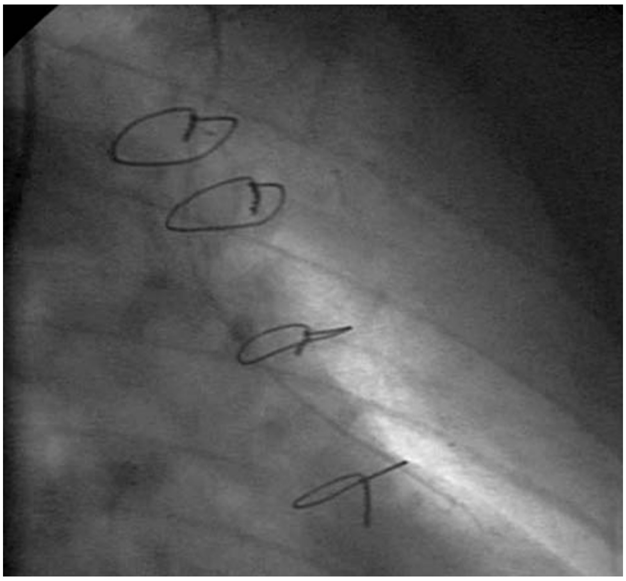

Figure 4. Patient T. String sign is observed in LITA to LAD.

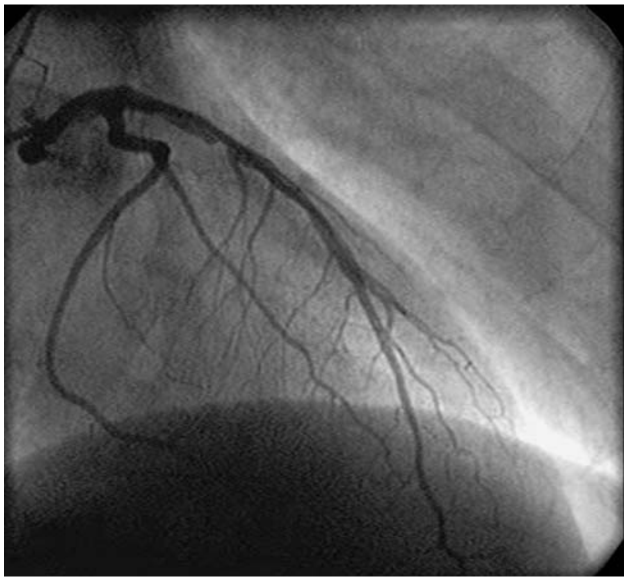

Figure 5. Patient T. Preoperative CAG. LAD proximal stenosis 75%.

Figure 6. Patient T. 6-month follow-up CAG: native part of LAD – proximal stenosis up to 70%. String Sign is observed in LITA to LAD.

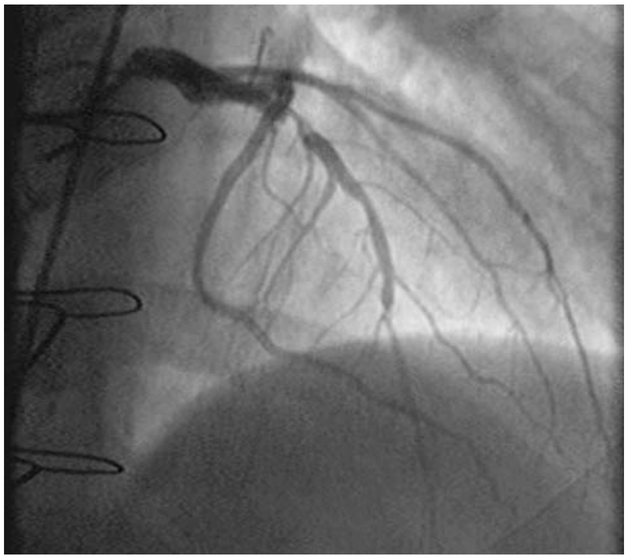

Figure 7. Patient T. 12-month follow-up CAG: LAD stenosis increased up to 85%.

fatuity of using RA and GEA in stenosis <85–90% has been already proven (23, 24).

The obtained results clearly indicate reverse proportional relationship between functional status of the mammary grafts and stenosis degree of the native CA.

This extremely adverse event is based on anatomy and physiology of arterial vessels. In contrast to venous conduits, ITA, RA, and GEA are muscular vessels (to different extent) and have self-regulation (16, 17). In non-critical CA stenoses, there is no necessity of additional blood flow which is required to preserve functions of arterial graft. As a result, the grafts become spastic, reduced and/or occluded (18).

However, the loss of pressure between proximal and distal parts is always observed in arterial grafts in contrast to venous ones. In non-critical stenoses, the pressure in the native artery distal to the stenosis is quite high. As a result, the pressure gradient between the graft and CA is reduced. Thus, blood flow through the conduit decreases. It is not difficult to imagine the situation when it may even reverse (18). Given the arteries work according to the law of demand for blood flow, they become spastic in the above situations. Owing to this particular event this phenomenon is observed more clearly in RA and GEA compared to ITA due to greater muscular layer and

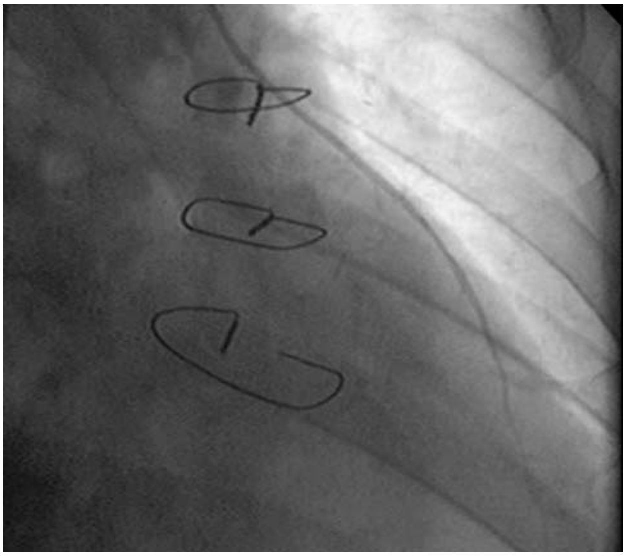

Figure 8. Patient T. Satisfactory function to LAD. 12 month follow-up CAG.

more pronounced tendency to spasm. Very interesting experimental studies (Karapanos, 2011) included quantitative analyses of blood flow through ITA graft depending on CA stenosis degree. The obtained results demonstrate that the blood flow though ITA is practically absent if stenosis degree is <70%, and it may be reversible if stenosis degree is <50%. The latter may lead to steal syndrome in the native artery.

The reduction of mammary graft in cases when neighbouring vessel with non-critical stenosis is revascularized with the vein we can explain using the following casual relationships: 1. The blood flow through the venous graft is 40–60% higher than through mammary artery due to large diameter and increased throughput capacity (19); 2. Therefore, the competitive blood flow in the vessel revascularized with mammary graft is created artificially; and 3. ITA is reduced and/or occluded. Our data are similar to results obtained by Joseph F. Sabik, III, MD (17).

There are no doubts that functional status of the grafts is multivariate and determined by both anatomy of the native artery (degree and extent of the lesion, vessel diameter, periphery status, etc.) and related hemodynamic disturbances.

However, in non-critical lesions, the surgeon should decide based on CA stenosis degree only: 1. which graft should be applied in a specific case?; 2. the “second vessel” should be grafted or not?; 3. if grafted, what type of conduit (arterial or venous) should be used?

Our results clearly demonstrate that ITA graft operates poorly when used for CA with isolated stenosis <75%. However, one should remember that so called “preventive CABG” (22, 27) may cause secondary injury in CA due to stenosis progression proximal to anastomosis (22). In non-functional graft, it may lead to repeat and quite often fatal acute coronary insufficiency.

The maximum accuracy of stenosis degree diagnostics is particularly important if two neighbouring vessels of the same arterial territory should be grafted in the lack of critical stenosis between them. In such cases, venous graft due to its anatomical and hemodynamic characteristics may be a reason for iatrogenic competitive blood flow in the neighbouring CA revascularized with mammary artery, and, as a consequence, its functional incompetence. Given that ITA revascularizes more significant vessel, the danger of this strategic error becomes apparent. This danger becomes especially great if the second vessel is LAD with significant proximal stenosis and/or LMCA critical stenosis. Our results and reports of Kawamura (2008), Norgaard (2009) clearly indicate it.

Based on the above mentioned, it is obvious that the maximum objective assessment of hemodynamic lesions in CA should be a starting point for determination of the revascularization strategy.

CAG is considered to be the “gold standard” of CA assessment. The indications for myocardial revascularization are based on its results. However, in doubtful cases and/or borderline stenoses it is reasonable to perform additional tests using direct hemodynamic assessments of blood flow in the affected vessels (fractional flow reserve – FFR).

Intravascular ultrasound (IVUS) also provides many essential data (Morton J. Kern, MD et.al (20), Soo-Jin Kang et. al (21)).

Therefore, there are no doubts that direct myocardial revascularization is the method of first choice in miltivessel disease. It is performed with hope for longevity. Therefore, correct understanding of factors affecting long-term functional status of the grafts is a single true approach to achieve this goal. Our results combined with objective analysis of the literature prove that:

1. Application of ITA for revascularization of CA with an isolated stenosis <70% is unreasonable due to high probability of graft reduction and occlusion;

2. In revascularization of non-critical stenoses, the venous conduits should be the method of choice;

3. If CAG results indicate that two neighbouring vessels of the same arterial territory should be grafted in the lack of critical stenosis between them, additional tests (IVUS, FFR) are reasonable to clarify the degree of intervascular stenosis;

4. If there is no critical stenosis between the vessels, revascularization of less significant vessel should be avoided, with obligatory follow-up (repeat CT, CAG) of the patient and his/her CA status and, if necessary, "delayed hybrid" PCI should be performed.

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Papillary Fibroelastoma. (Successful Removal of the Rare Type of Papillary Fibroelastoma from the Pulmonary Valve)

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The benign cardiac tumors are rare. Diagnostics is primarily based on incidental EchoCG exams of patients. The article contains data on diagnostics, clinical course, and possible complications of papillary fibroelastoma and presents a case of successful removal of the rarest type of papillary fibroelastoma located in the pulmonary valve.
***Key words:** cardiac tumor, papillary fibroelastoma, clinical course, diagnostics, complications, and surgical treatment of papillary fibroelastoma of the heart.*

Primary heart tumors including autopsy data are observed in 0.002–0.033% of cases (1, 2). The portion of benign tumors is about 80% (3). Papillary fibroelastomas (PFE) are the third most common tumors following myxomas and lipomas. They comprise about 10% of all primary cardiac neoplasms (4, 5, 6).

Although PFE belongs to benign tumors, it may frequently cause fatal embolic complications (4–9). Therefore, early diagnostics and timely surgical treatment are especially important (8–10).

The first case of PFE surgical removal was reported by Lichtenstien et al. in 1976 (11). To date, there are approximately 1,000 reports about successful surgeries for PFE in the world literature (9, 15). But the reports on successful removal of this tumor from the pulmonary valve are scarce (9).

Primary cardiac tumors were successfully removed in 23 patients who were treated at the Cardiosurgery Department of the State-Funded Healthcare Institution Moscow City Centre of Interventional Cardioangiology, Moscow Healthcare Department. Left atrial myxomas were removed in 21 cases and 1 case presented “twins”, i.e. lipomas located on the free right atrial wall (3).

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Given papillary fibroelastoma of PA valve is a very rare event, we considered it necessary to share our experience of its successful removal keeping anatomical and functional integrity of the cusps.

Female patient N., Case History #1299 was admitted to the Cardiosurgery Department of the Moscow City Centre of Interventional Cardioangiology on March 20, 2014 with diagnosis of neoplasm of the pulmonary valve.

Medical history: Essential hypertension, stage II. Lately, she had heart irregularity, moderate dyspnea on exertion. Due to these complaints, the patient went to the Polyclinic at her place of residence. EchoCG revealed a tumor located in the projection of the pulmonary valve; the patient was referred to our Centre. Transesophageal EchoCG (January 10, 2014) revealed the following: left ventricle contractility was adequate; EF – 62%; cardiac cavities not dilated; aorta with moderate sclerotic lesions, not dilated; pulmonary trunk (PT) not dilated, with diameter of 26 mm. The mobile tumor with well-defined contours attached to the posterior cusp with its wide basis was visualized on the pulmonary valve. The tumor changed its shape depending on cardiac cycle, with mean dimensions 1.7 × 1.7 cm. The maximum early systolic gradient on the pulmonary valve was 21 mmHg and PA systolic pressure was 27 mmHg. ECG revealed sinus rhythm. X-ray and other clinical and laboratory investigations revealed no concomitant pathology. Coagulogram was normal. The diagnosis was as follows: neoplasm of the pulmonary valve (papillary fibroelastoma?).

On March 25, 2014 under the conditions of normothermic cardiopulmonary bypass and antegrade cardioplegia (Custodiol) modified at out Centre, the following surgery was performed: excision of neoplasm of the pulmonary valve keeping cusps integrity. Cardiopulmonary bypass was performed via separate cannulation of the venae cavae and aorta. Following cardiac arrest, PA trunk was incised via longitude incision (3 cm) starting approximately 2 cm from the fibrous annulus. The villous yellow-white tumor measured approximately 2.0 × 2.0 cm, which basis was attached to the posterior cusp of the pulmonary valve was detected. Given the papillary filaments are very fragile and iatrogenic embolism is possible, a gauze pad was placed into PA trunk directed to its branches, and tumor was put onto a teaspoon and only after that was sharply separated from the cusp and removed. The performed water test demonstrated a complete integrity of the anatomy and hemodynamic function of the PA valve. PA truck was repaired using two-row blanket stitch. After taking the clamp off the aorta, the heart activity restored spontaneously. The rhythm was sinus. Duration of the cardiopulmonary bypass was 43 minutes. Duration of the aortic cross-clamping was 32 minutes. The postoperative period was unremarkable. Postoperative EchoCG revealed complete competency of the pulmonary valve and lack of additional Echo-signals at its cusps. On the 12th day after surgery the patient was discharged home in satisfactory condition.

The removed material was transferred to N.N. Sklifosovskiy Scientific Research Institute for histological examination. Macroscopic investigation dated March 31, 2014 – whitish soft stringy tissue measured 2 × 2 × 0.5 cm. Histological picture: papillary fibroelastoma.

Discussion

Papillary fibroelastoma is found in approximately 1/12,500 necropsies (1–5). However, it may cause very dangerous complications due to its structural characteristics (9). Thus, the diagnostics and surgical treatment should be performed in timely manner.

PFEs are usually single tumors (3). The multiplicity is observed in 7.5% of cases only (5, 8, 12, 13). The dimensions of PFE may vary from 0.1 to 7.0 cm, but not exceeding 1.5 cm in most cases. (1, 2, 9).

PFEs look like a bush with many thin branches with one pedicle attached to the valvular surface or endocardium of the heart. The pedicle is a terminal part of the stem which is typical for this tumor. The histological composition of the papillary branches is represented by centrally

Figure 1. EchoCG. Neoplasm (2 × 1.8 cm) is observed near the pulmonary valve.

located solid body made of connective tissue, surrounded with incompact connective tissue and covered with superplastic elastic endothelial cells (1.2).

When PFEs are immersed in the water, they take the shape of sea anemone (sea actinia – a group of sea coral polyps called anemones for their unusual beauty) (1.2).

In 84–90% of cases (1, 3, 8, 10) PFEs are located on the cardiac valves, mostly on the aortic valve (9). They are located on ventricular surfaces of the cusps as often as on aortal ones (1, 2, 3). The mitral valve is the next most frequent place (10). The tumor may be located both on the cusps and chords or papillary muscles (10). If the tumor is on the cusp, it is usually its mid-part and its atrial surface. PFEs are rarely observed in the tricuspid valve and PA valve. In 15.7% of cases PFEs may be located in the inner ventricular or atrial wall. 81% of all surgically removed PFEs were located in "arterial" part of the heart (1).

PFEs are generally diagnosed in patients older than 60 y.o. although there are reports about this tumor in newborns and patients older than 90 y.o. (7, 8, 10).

There are no specific symptoms of PFE. In general, these tumors are characterized with clinical signs of complications caused by these tumors. First of all, these are symptoms of embolic injuries of the vascular territories located antegradely from the tumor. Thus, in case of the most frequent so called arterial location (aortic valve, mitral valve, left ventricle wall), PFE is manifested as transient brain ischemic attacks and strokes; acute myocardial infarction with the evidence of heart failure, sudden death; pre-syncope and syncope; sudden blindness and various acute peripheral

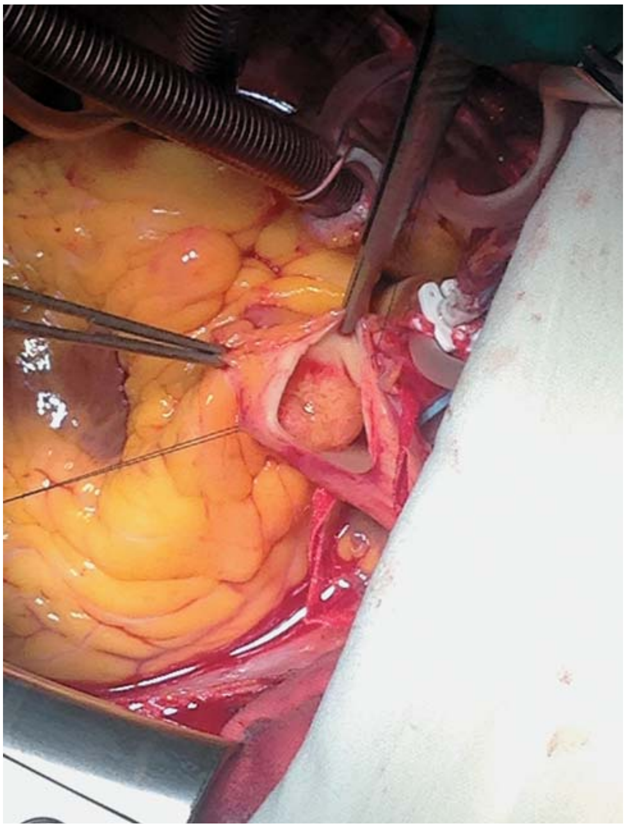

Figure 2. The trunk of the pulmonary artery is opened. Papillary fibroelastoma of the pulmonary valve is visualized.

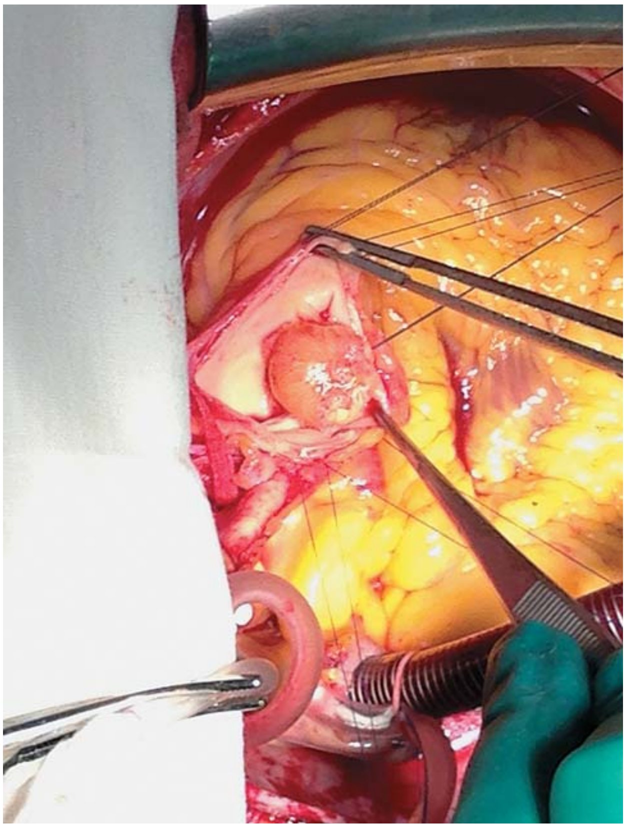

Figure 3. The tumor pedicle originates from the posterior cusp of the pulmonary valve.

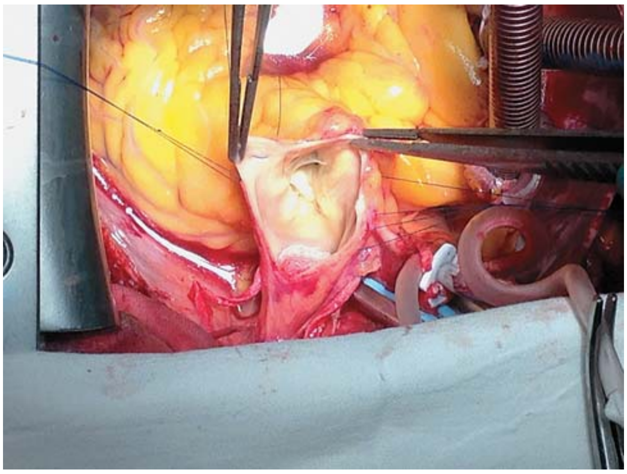

Figure 4. The tumor is removed. Water test demonstrates that obturative function of the pulmonary valve is preserved.

Figure 5. Papillary fibroelastoma takes typical villous shape in the saline.

ischemic lesions (9, 10, 12, 18). The literature describes cases of LMCA obstruction caused by PFE located on the right coronary cusp of the aortic valve (14). If PFE is located in the right (so called "venous") chambers (right atrium, tricuspid valve, right ventricle, and pulmonary valve), PE signs and obstruction of outflow tract of the right ventricle may be present (5, 7, 8).

The cause of embolization is fragmentation of papillary filaments of the tumor itself or thrombi which may form around the neoplasm. Actually, the tumor may be a "nest" for aggregation of platelets and fibrin, which consequently expulse as emboli (1, 2, 5).

EchoCG is the most available option for PFE diagnosis (18). Transesophageal EchoCG provides contours, anatomy and topography even of the smallest tumors. PFEs look like round, oval or uncertain tumors with well-defined demarcation edges and homogenous structure, mostly no more than 2 cm. In the vast majority of cases, they are solitaire and located on the cusps. In more than half of all cases the tumor is quite mobile and has typical small stem (2). It should be noted that even transesophageal EchoCG may provide false negative results, if: 1. tumor is masked with another concomitant disease; 2. it is very small; 3. test was carelessly performed with low suspicion index; and 4. there are no significant typical signs, which would be enough to differentiate from other degenerative cusp disorders (7, 17).

Therefore, when thromboembolism of uncertain origin may underlie the disease, EchoCG should be performed. This especially applies to young patients with transient ischemic stroke or ischemic heart attack even in the absence of ECG evidence of heart pathology. If mobile tumor is revealed, transesophageal EchoCG should be carefully performed (3) to determine its sizes, configuration, localization, amount, and presence of the stem typical for PFE. The tumor looks like a centrally located, high-contrast core, which is surrounded with less contrast part of the tumor. The differential diagnosis should include: septic endocarditis with the valve vegetations; presence of intravascular thrombi; degenerative changes on the cusps, and other tumors. In the majority of cases, all these conditions have typical clinical and laboratory signs and can be excluded.

The indications for surgery depend on localization and clinical manifestations. Left-sided tumors should be removed urgently, except for those ≤1 cm, if they are fixed and have no stem (2). However, such patients should be regularly monitored using EchoCG, and, if signs or mobility appear, the surgery should be performed immediately. The symptomatic patients should be operated urgently. The mobility of the tumor increases manyfold its embolism potential and is an independent risk factor for both fatal and non-fatal complications. Therefore, the mobile tumors should be removed regardless of their dimensions. The right-sided tumors should be removed immediately, if they are mobile, have big sizes, cause outflow tract obstruction or pulmonary embolism (3). If the tumor is located in the right atrium and right-to-left shunt through the patent foramen ovale (PFO) is present, the tumor should be removed urgently. Due to high cumulative risk for embolism, this indication is especially important for young patients with low surgical risk. The tumor should be removed in all cases if another cardiac surgery is scheduled (16).

In the literature there are no data on reoccurrence of PFE after its removal (9). Therefore, timely surgery using all required measures to prevent iatrogenic embolism along with valve-sparing strategy ensures successful intervention and sustained long-term results.

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There's Never a New Fashion But it's Old (Geoffrey Chaucer)

D.G. Iosseliani

A note from the Editor-in-Chief

At present the clinicians and the researchers make a good use of the SYNTAX SCORE (Synergy Between PCI With TAXUS and Cardiac Surgery), which allows them to give an objective and quantitative evaluation of the cumulative severity of the coronary bed affection by the occlusive and stenotic process [(1)]. One hardly can overestimate the significance of this method allowing to assess the severity of the disease and, what is by no means less important, to predict the risk of surgical as well as of endovascular interventions in cardiac patients. Without lessening the merits of this score's designers, we consider it fair to remind the colleagues, that in the past, the attempts had been made to create similar systems, and not without success.

The above can be illustrated by the method of integral estimation of the state of the coronary bed in coronary heart disease cases, suggested by the late professor Yuri Petrossian and your "obedient servant" (Bakoulev Institute for Cardiovascular Surgery, Moscow, USSR). An article describing this method was published in Russian, but with an English abstract in the Soviet journal "Kardiogia" (Cardiology) - 1976, №12, pp. 41-46. In our opinion, it is interesting to publish this article in our journal in its entirety, without any cuts or changes.

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ON SUMMATED ASSESSMENT OF THE STATE OF THE CORONARY BED IN ISCHAEMIC HEART DISEASE CASES

Yu. S. Petrosyan, D. G. Ioseliani

Summary

A method of summated assessment of atherosclerotic lesions in the coronary bed of patients with ischaemic heart disease based on selective coronary angiography data is introduced. To simplify the calculations of the total lesion of the coronary bed a special chart-table was complied that permits to determine the percentage of the lesion. A unified assessment of the degree of the coronary lesions will permit to interpret in comparable values the state of different groups of patients, the efficacy of different therapeutic methods, and will permit to determine the correlation of clinical, electrocardiographic, haemodynamic and other parameters with the degree of the lesion. The introduced technique of determining the total lesion of the coronary bed takes into account narrowings exceeding 50% of the arterial lumen, the type of blood supply to the heart, the localization of the narrowings, the effect of centrally located narrowings upon the subsequent stenoses of all the most important arteries of the heart. The conducted comparisons have demonstrated a high degree of correlation between the frequency of anginal attacks, the tolerance of physical exercises, the level of end-diastolic pressure in the left ventricle, and the severity of the lesion in the arterial bed.

On Summated Assessment of the State of the Coronary Bed in Ischaemic Heart Disease Cases

Yu.S. Petrosyan, D.G. Iosseliani

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The introduction of selective coronary angiography and ventriculography into clinical practice allowed us to study a number of inarguably important parameters related to myocardial contractility and occurrence of coronary artery atherosclerosis. Particularly, selective coronary angiography allowed us to determine stenosis degree and localization, type of blood flow, collateral flow intensity etc.

Thus we have gained real ability to compare clinical, electrocardiographic and other parameters with severity of coronary artery disease.

The classification of coronary artery atherosclerotic disease we proposed was accepted by II All-Union Symposium (4) and allowed objectification and much easier comparison of studies performed by various authors. But clinical practice shows that evaluation of coronary artery disease by affected arteries count or by stenosis degree doesn't give us the full picture of disease. These disadvantages become clearly visible while comparing different groups of patients or finding correlations between clinical, electrocardiographic and hemodynamic data.

Besides, speaking of surgical treatment, we have to assess not only the localization and severity of lesions but the whole sum of pathologic findings, since this factor is the most important in determining the result of operation and may serve as a kind of predictor.

Absence of quantitative assessment of coronary vessels condition leads to the lack of objectivity in different patients groups' characteristics and comparison of different treatment methods. We can only speak of advantages and disadvantages of different treatment options if we have possibility to evaluate patients' condition objectively.

Clinical and electrocardiographic assessment criteria used nowadays are pretty much subjective and doesn't give the full picture of disease.

We have reported our first attempt of evaluation of coronary vessels state using selective coronary angiography and comparison of this data with hemodynamic findings on II Union Symposium (5). Few attempts of such kind were reported earlier (11, 12, 14–16), but practice revealed their inconsistency. Some of them didn't consider type of coronary blood supply (6), other didn't consider possibility of left main artery disease (11, 16) or their criteria of assessment weren't always logical or they didn't consider importance of possible important branches disease (13–15).

We realize all the difficulties of intravital assessment of coronary artery disease. The most important of them are following: 1) variety of coronary blood supply types, defining different importance of various arteries to the myocardium supply; 2) various degrees of lesions up to total occlusion; 3) various localizations of lesions (proximal or distal); 4) influence of proximal stenosis on distal lesions in the same artery. Besides, there is number of other coronary blood supply features related to age, sex, constitution and etc, assessment of which via coronary angiography is difficult.

In attempt to take into account all these factors the method of coronary arteries disease assessment can become too cumbersome and difficult to use in clinical practice. Oversimplifying of the method, however, will make the assessment too inaccurate.

As a result of numerous attempts we have developed the method that considers following factors: 1) coronary artery lesion over 50% and occlusions; 2) coronary blood supply type; 3) lesions localization; 4) influence of proximal stenosis on distal lesions in the same artery; 5) left main artery, left anterior descending artery, diagonal artery, circumflex and obtuse marginal arteries, right coronary artery and her marginal branch disease.

Weale (17) showed that lesions less than 50% are not hemodynamically significant thus we only considered those that are over 50%.

We divided all main arteries into three segments because of greater significance of proxi-

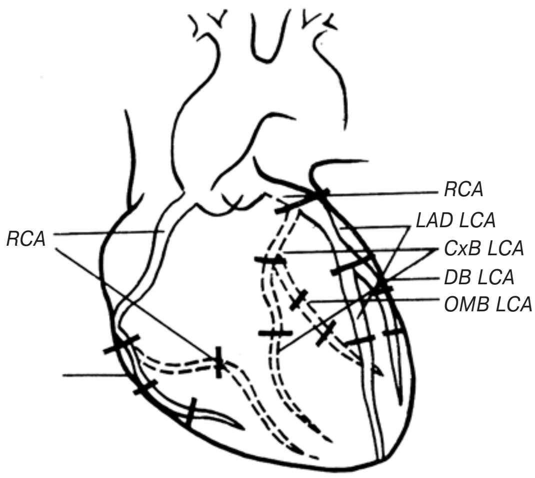

Fig. 1. Scheme of the coronary arteries. RCA – right coronary artery; AMB RCA – acute margin branch of the RCA; LCA – left coronary artery; LAD LCA – left anterior descending branch of the LCA; CxB LCA – circumflex branch of the LCA; DB LCA – diagonal branch of the LCA; OMB LCA – obtuse margin branch of the LCA.

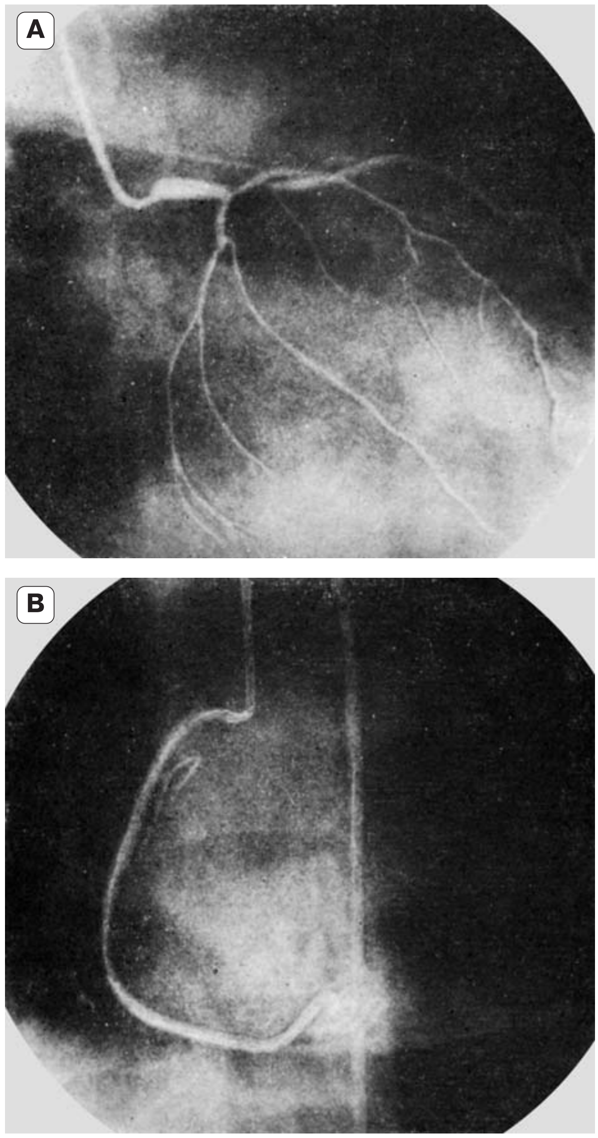

Fig. 2. Coronary angiograms. A – right oblique view; B – direct view.

mal lesions and assessed each segment individually. Left main artery disease is specified individually as it occurs in more than 15% of all patients and is of great importance (Fig. 1).

Evaluation of all coronary vessels is conditionally considered 240 points. This number is roughly equal to the amount of blood flow per one minute. According to Cohen et al. and Cowan et al. (9, 10) blood flow measured using rubidium-84 was 250 and 237 ml per minute respectively.

We have divided his conditional number (240) to main coronary arteries according to considered blood flow characteristics.

Diagonal artery assessment expedience is proved by the incidence of its disease: 17% according to our data and 90% according to N.A. Dzhavakhashvili and M.E. Komakhidze. In majority of cases it arises from left main artery itself, thus forming a trifurcation (1, 2, 7, 8). We also assessed obtuse and acute marginal arteries due to the same reason.

The chart was developed for assessment simplification and unification.

Using the chart and assessment of coronary arteries disease are easier to learn through examples.

As seen in coronary angiogram presented (Fig. 2, A, B) the patient has severe local stenosis (over 75% or III degree) of left anterior descending artery and diagonal artery ostia while other arteries are apparently intact.

The first step is determining blood supply type. In this case the type is right and left main artery is intact thus all the calculations are performed according to specified graph of the chart. Proximal segments of both diseased arteries with lesions over 75% (III degree) are evaluated to 34 and 3 points respectively, 37 points in total. It is more convenient to express this number in percents.

$$\text{Total coronary artery disease (\%)} = 37/240 \times 100 = 15{,}42\%.$$

The disease of left and right arteries can be evaluated separately. The denominator should be the number of total points of given artery according to the type of blood flow for such calculation. Left artery in this example should be evaluated to 120 points, thus total disease count for left artery is 30.83%.

Fig. 3 demonstrates total occlusion of left main coronary artery. The whole system of left

The chart for assessment of total coronary arteries disease

Type of blood flow:	Lesion degree, %	Left main coronary artery	Left anterior descending artery			Diagonal branc			Circumflex artery			Obtuse marginal branch			Right coronary artery			Acute marginal branch		
			pr*	md	ds	pr	md	ds	pr	md	ds	pr	md	ds	pr	md	ds	pr	md	ds
Left:																				
with left main	100	180	20	10	5	10	6	4	20	10	5	10	6	4	50	25	13	10	6	4
coronary artery	75	120	9	4	2	3	2	1	9	4	2	3	2	1	23	12	6	3	2	1
disease	50	100	4	2	1	2	1	0	4	2	1	2	1	0	11	5	3	2	1	0
without left main	100		70	35	18	20	10	5	70	35	18	20	10	5	50	25	13	10	6	4
coronary artery	75		34	16	9	9	4	2	34	16	9	9	4	2	23	12	6	3	2	1
disease	50		15	8	5	4	2	1	15	8	5	4	2	1	11	5	3	2	1	0
Balanced:																				
with left main	100	160	30	10	5	10	6	4	20	10	5	10	6	4	60	30	15	20	10	5
coronary artery	75	100	9	4	2	3	2	1	9	4	2	3	2	1	28	14	8	9	4	2
disease	50	80	4	2	1	2	1	0	4	2	1	2	1	0	14	7	4	4	2	1
without left main	100		70	35	18	20	10	5	50	25	13	20	10	5	60	30	15	20	10	5
coronary artery	75		34	16	9	9	4	2	23	12	6	9	4	2	28	14	8	9	4	2
disease	50		15	8	5	4	2	1	11	5	3	4	2	1	14	7	4	4	2	1
Right:																				
with left main	100	120	20	10	5	5	3	2	10	6	4	5	3	2	100	50	25	20	10	5
coronary artery	75	80	9	4	2	2	1	0	3	2	1	2	1	0	45	22	11	9	4	2
disease	50	60	4	2	1	1	0	0	2	1	0	1	0	0	21	10	5	4	2	1
without left main	100		70	35	18	10	6	4	30	15	7	10	6	4	100	50	25	20	10	5
coronary artery	75		34	16	9	3	2	1	13	6	4	3	2	1	45	22	11	9	4	2
disease	50		15	8	5	2	1	0	3	2	1	2	1	0	21	10	5	4	2	1

All coronary vessels in total – 240

Left coronary artery –
Right coronary artery –
Total coronary arteries disease –

* pr – proximal, md – mid, ds – distal.

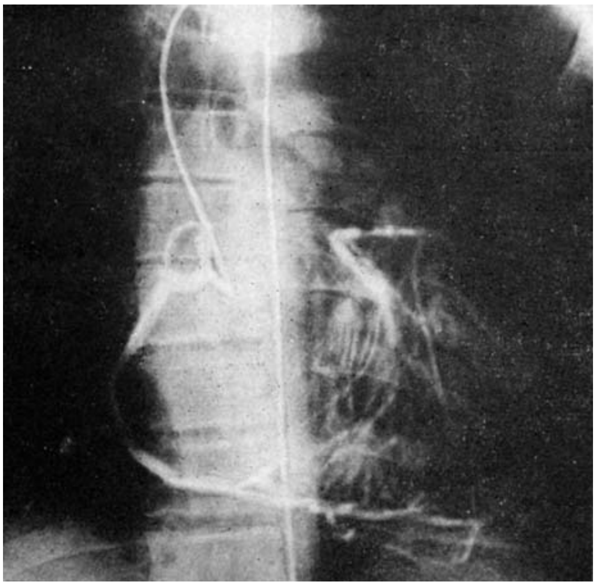

Fig. 3. Coronary angiogram. Direct view.

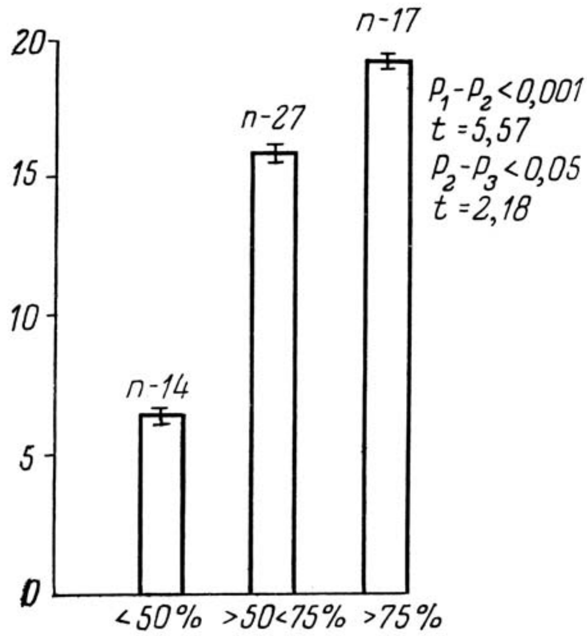

Fig. 4. Correlation between severity of coronary artery disease and frequency of anginal attacks.
X – severity of coronary artery disease (in %); Y – frequency of anginal attacks.

main coronary artery is filled with contrast medium from right coronary artery via collaterals. Note that right coronary artery has 50% stenosis of distal segment.

The patient has right type of coronary blood supply and left main coronary artery disease. Occlusion of left main coronary artery evaluates to 120 points, whereas distal right coronary artery stenosis evaluates to 5 points, thus the total score is 125 points, or 52%.

The chart needs some explanations. In cases when diagonal artery arises from left anterior descending artery distal to the site of occlusion or stenosis it should be taken into consideration too. For example if left anterior descending artery is occluded in proximal segment (balanced type of coronary blood supply without left main artery disease), 20 points for the diagonal artery must be added to 70 points for left anterior descending artery. Thus proximal occlusion of left anterior descending artery should be evaluated to 90 points. Same calculation should be performed in case of occlusion of right coronary artery of circumflex artery.

Second explanation – occlusion of coronary artery can only be considered as proximal segment occlusion if it is located proximally to the side branches.

We have experienced great difficulties in earlier researches while comparing clinical or hemodynamical data with coronary vessels state. Using this method we acquired real possibility of finding correlations between these findings. Value of this data can be demonstrated through some examples.

Following data was compared to evaluate correlation between the frequency of angina attacks in stable coronary artery disease and coronary vessel state (Fig. 4).

All patients were divided into three groups. First group included patients with total coronary artery disease score less than 50%, second group included patients with score over 50%, and third – over 75%. It appeared that in second group frequency of anginal attacks was 2 1/2 higher than in first group, and in third group – 3 times higher. The difference between second and third group was lower but also significant ($p < 0.05$).

Thus we can see correlation between severity of coronary artery disease and frequency of anginal attacks, making it possible to assume coronary vessel state according to clinical findings.

We have compared tolerance of physical effort to coronary artery disease status to find correlations between them (Fig. 5). Strong reverse correlation ($r = -0.741$) is obvious. Tolerance of physical effort reduces when severity of coronary artery disease is increased.

The increase of end-diastolic pressure in left ventricle is one of the signs of its contractility disorder.

Level of end-diastolic pressure in left ventricle determined via its catheterization was compared with data on coronary artery disease

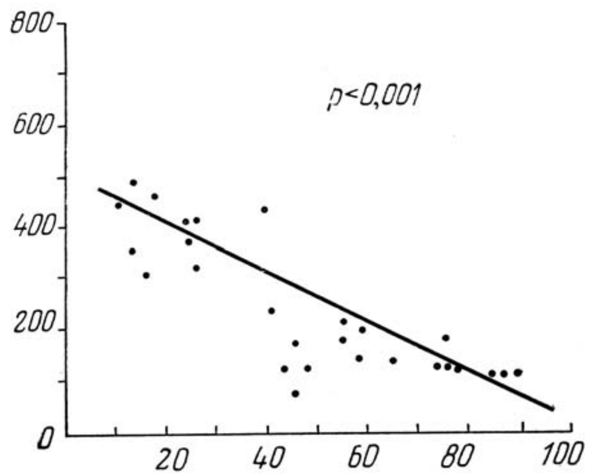

Fig. 5. Correlation between tolerance of physical effort and coronary artery disease status.
X – severity of coronary artery disease (in %); Y – physical effort (KGM/min).

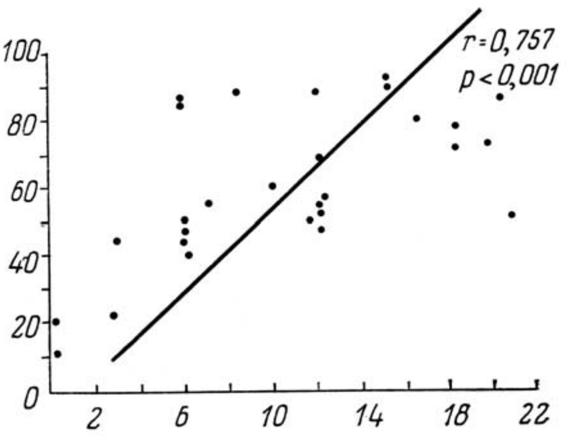

Fig. 6. Correlation between end-diastolic pressure in left ventricle and coronary artery disease status.
X – end-diastolic pressure in left ventricle (in mm Hg). Y – severity of coronary artery disease (in %).

(Fig. 6). As seen there is direct correlation between these findings. The level of end-diastolic pressure in left ventricle is increased along with increasement of coronary artery disease score (r = 0.757, $p < 0.001$). It is obvious that patients with score less than 50% never had their end-diastolic pressure over 12 mmHg.

We suppose that our method is still imperfect, but, as is shown by clinical practice it has inarguable advantage over simple counting of lesions and their degree as it also considers hemodynamic significance of them.

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