Evaluation of Complications Predictors in the Performance of Coronary Artery Bypass Grafting Surgery in the Cardiac Surgery Clinic "Bicard"

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HIGHLIGHTS

- Acute myocardial infarction in anamnesis is the main factor complications occurrence after coronary artery bypass grafting
- Predictors are also named low left ventricular ejection fraction (less than 40%), left ventricular diastolic dysfunction of and duration of procedure of artificial circulation
- Left ventricular diastolic dysfunction is the most specific predictor

SOUHRN

Hlavním cílem práce byl komplexní výzkum a stratifikace klinických, funkčních a chirurgických rizikových faktorů z hlediska vzniku komplikací koronárního bypassu v předoperačním období.
Materiály a metody: Byly analyzovány údaje 97 pacientů ve věku 31–84 let (průměrný věk 62,9 ± 8,4) s ischemickou chorobou srdeční po koronárním bypassu (v mimotělním oběhu). Za prognostická kritéria posloužil věk pacienta, přítomnost akutního infarktu myokardu v anamnéze, délka hospitalizace, počet zkratů, délka komprese aorty i trvání mimotělního oběhu. Mezi sledované parametry patřily rozměry levé komory na konci diastoly a systoly, anteroposteriorní rozměr levé síně, tloušťka mezikomorového septa a spodní stěny levé komory, ejekční frakce levé komory, přítomnost a rozsah mitrální regurgitace a dysfunkce levé komory v diastole.
Výsledky: Sledování klinických, funkčních a chirurgických rizikových faktorů pro rozvoj komplikací koronárního bypassu prokázalo nejvyšší senzitivitu akutního infarktu myokardu (v anamnéze i těsně před výkonem) a nejvyšší specificitu diastolické dysfunkce levé komory.
Závěr: Jako nejvýznamnější prediktory vzniku komplikací koronárního bypassu v pooperačním období byly identifikovány akutní infarkt myokardu, ejekční frakce levé komory < 40 %, přítomnost diastolické dysfunkce levé komory a délka použití mimotělního oběhu.

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ABSTRACT

The main aim of the research was to do the complex research and stratification of clinical, functional, and surgical risk factors for coronary artery bypass grafting complications development in the preoperative period.
Materials and methods: Data of 97 patients with coronary heart disease aged 31–84 (the mean age 62.9±8.4) after coronary artery bypass grafting (with the artificial circulation) have been analyzed. As prognostic criteria were analyzed the patient's age, a history of the acute myocardial infarction, hospitalization time, number of the placed shunts, aortic compression duration, as well as the duration of the artificial circulation

system, using. End diastolic and end systolic dimensions of the left ventricle, anteroposterior dimension of left atrium, thickness of interventricular septum and posterior wall of the left ventricle, left ventricular ejection fraction, presence and extent of mitral regurgitation, left ventricular diastolic dysfunction were studied.
Results: Studies of the clinical, functional, and surgical risk factors of coronary artery bypass grafting complications development have shown the highest sensitivity for acute myocardial infarction (both history and immediately before surgery), and the highest specificity for the presence of left ventricular diastolic dysfunction.
Conclusion: Acute myocardial infarction, left ventricular ejection fraction less than 40%, presence of left ventricular diastolic dysfunction, and the duration of application of the artificial circulation system were fixed as the most important predictors of coronary artery bypass grafting complications development in the postoperative period.

Introduction

Currently coronary artery bypass grafting (CABG) surgery became one of the most effective methods of treatment of coronary heart disease (CHD). Volume of these interventions is increasing each year, including the Kyrgyz Republic.[1–3] Increasing of the number of such operations is accompanied by the increase in the frequency of complications in preoperative period due to increase in the number of elderly and senile patients often admitted to surgery with severe comorbidities.[4,5] Moreover, the most frequent complications are the development of acute heart failure (AHF), renal dysfunction, long-term invasive ventilation, hemodynamic instability, and various heart's rhythm disorders.[6–8]

The results of vascularization, identification, and stratification of predictors of complications development are extremely important for improvement. Based on the obtained data the risk of complications occurrence can be predicted. This allows the creation of a system of preventive measures.

Despite a large number of research works, estimating risk factors of different complications, their results remain quite contradictory. In our opinion, the main reason for such discrepancies is differentiation in the level of equipment, and the difference in the number of patients involved in the researches, the difference in the qualifications of specialists conducting operation interventions (including CABG). Therefore it remains relevant to identify and stratify predictors of the development of complications during the preoperative period of CABG specifically for each medical establishment.

The aim of this study was to study and stratify clinical, functional, and surgical risk factors for complications in the preoperative period of CABG in order to develop measures to reduce the number of complications in a private cardiology clinic.

Material and methods

The research has been based on materials of the 97 patients with CHD at the age from 31 to 84 years old (the average age is 62.9±8.4 years). Among patients prevailed males (86.6%); the number of women was significantly inferior 13 patients (13.4%). The CABG surgery was performed to all patients in the conditions of artificial circulation (AC) according to the generally accepted method. All actions of the conducted research have been conside-red at the meeting of the Bioethics Committee. Protocol 13 from November 2 2021 declared that current research has been conducted according to the ethical principles for medical research involving human subjects (Helsinki, June 1964, with later amendments till October 2008).

In order to control the treatment process, Echocardiographic (EchoCG) examination was performed with use of VIVID 7 apparatus; M,-B-modes and dopplerography were also used.

Patient's age, presence of previous acute myocardial infarction (AMI), length of hospitalization, placed shunts number, duration of aortic compression, and duration of Artificial Circulation were studied as prognostic criteria. Left ventricular end diastolic dimension (LVEDd) and left ventricular chamber diameter at end systole (LVDS), anteroposterior size of left atrial (LA), thickness of interventricular septum (IVS), and posterior wall (PW) of the left ventricle, left ventricular ejection fraction (LVEF), presence and stage of mitral regurgitation (MR), and diastolic dysfunction of the left ventricle (DDLV) were used following EchoCG indicators.

Statistical analysis
Statistical processing was performed using the statistical package SPSS Version 16. Mean and standard deviations were calculated as descriptive statistics. The odds ratio and 95% confidence interval were calculated to assess the association of the presumed predictor and the occurrence of complications. For the main predictors, values of sensitivity (Se), specificity (Sp), prognostic predictive value (Ppv) and negative predictive value (Npv). The level of statistical significance was taken $p = 0.05$.

Results

Clinical characteristics of patients
All patients prior to operation were diagnosed with stenocardia of 11-1V Functional Class (FC) according to the Classification of Canadian Association of Cardiologists. 62 patients (63.9%) suffered from AIM. And in anamnesis this pathology was detected during the preoperative period remotely in 82.3% (51), immediately before AIM intervention 11 patients (17.7%) came through. CABG surgery was not performed to anyone of the patients enrolled in the research previously.

Clinical signs of chronic heart failure (CHF FC 1-111 Stage according to the New York Heart Association Classification) were detected in 87.6% ill people (85 people).

Co-existing arterial hypertension was detected in 79 (81.4%) people. Was analyzed the body mass index (BMI) of patients. BMI was 30.2+3.0 kg/m^2. Has been indicated the presence of overweight in most patients.

Hypercholesterolemia has been diagnosed in patients (85.6%), in this case the total cholesterol was >4.5mmol/L. Performing EchoCG volume LVEF ranged from 25% to 65%, averaging 44.8+8.7%. In 29 people (29.9%) LVEF was recorded less than 40%. Signs of postinfarction aneurysm of LV were diagnosed in 9 (9.1%) people. Volumes of LA ranged from 28 mm to 61 mm (average 40.4+6 mm), and volumes of LV – EDD from 43 to 74 mm (average 62.9+8.4 mm), ESD from 20 to 63 mm (average 39.6+6.7 mm). LVDD was detected in 32 patients (33%) and MR in 31 ill people (32%).

Treadmill test before surgery was performed in 53 patients (54.6%). Its result was positive for everyone. Multivessel disease of coronary arteries was observed according coronarography data of all patients.

In performing the CABG the duration of AC was from 56 to 270 min (average 131.9+53 min), and the duration of aortic compression was from 14 to 180 min (average 65.7+41 min). The average number of shunts per one patient was 2.8+0.4 (from 1 to 5).

The average hospitalization time was 7.5+3.7 days. The total hospital mortality was 3.4%. And this is comparable to the world standards. In the world practice, hospital mortality in this case does not exceed 1–3%.[9] In the same time the mortality of patients with low LVEF (>40%) was 9.1% (3 cases out of 33 patients).

Evaluation of predictors of post-operative complications

Our research has demonstrated that acute heart failure (AHF) had developed (or progressed) in the intraoperative and early postoperative periods in 31 patients out of 97. At the same time, it was manifested by pulmonary edema, cardiac asthma, cardiogenic shock, acute heart rhythm disorders in the form of ventricular tachycardia with the transition to ventricular fibrillation, flickering and fluttering of the atria. Study of clinical, functional, and surgical risk factors of complications development in the intraoperative and early postoperative periods of CABG showed the following results (Table 1).

We have not found a significant dependence of the complications occurring and the age of the treated patients (Table 1). And the length of AC period and aortic compression time have not shown a statistically significant effect on the development of the cardiac complications in our research. So more, the number of applied shunts was not also closely connected with complications development in our research. But the myocardial infarction has demonstrated the dependence. So, AMI in anamnesis and immediately prior to CABG were the factors of the highest risk of postoperative complications development in our research.

If we consider the length of hospitalization as an indicator of the complicated course of postoperative period, we have not found such dependence.

We have taken as the base that echocardiographic indicators such as LVEF, DDLV stage, and MR are of the closest dependence related to cardiac complications. And

current observation has approved this but other echocardiographic indicators, like heart size, IVS thickness, and LVPW, didn't show such dependence. Moreover, length of the artificial circulation period, aortic compression time as the length of the artificial circulation period and aortic compression time had no the significant influence on the development of the post-surgery complications in cardiac surgical patients. The most significant predictors of mortality were hemodynamic instability and renal dysfunction according to our observation. And the LVEF had great connection with post-surgery complications development.

Table 1 – Data on odds ratio for studied parameters		
Parameters	**Odds ratio 95% CI**	**p**
Acute myocardial infarction	11.194 (2.457–50.993)	0.000
Age	2.240 (0.992–5.445)	0.996
Diastolic dysfunction of left ventricular	2.593 (1.048–6.415)	0.147
Left ventricular ejection fraction	6.175 (2.391–15.948)	0.004
Left ventricular end diastolic dimension	0.922 (0.371–2.295)	0.315
Left ventricular chamber diameter at end systole	0.557 (0.225–1.380)	0.154
Interventricular septum thickness	1.955 (0.591–6.464)	0.968
Thickness of left ventricular posterior wall	1.504 (0.478–3.559)	0.673
Mitral regurgitation	0.627 (0.232–1.696)	0.223
Length of hospital stay	0.134 (0.029-0.621)	0.002
Anteroposterior volume of the left ventricle	0.615 (0.097–3.905)	0.418
Number of shunts	0.459 (0.120–1.751)	0.246
Length of aortic compression	0.593 (0.122–2.887)	0.516
Length of AC period	0.889 (0.186–4.244)	0.883

Table 2 – Predictive ability estimations of the major predictors				
Parameters	**Sensitivity value**	**Specificity value**	**Positive predictive value**	**Negative predictive value**
Acute myocardial infarction	0.92	0.46	41.9	93.9
Left ventricular ejection fraction	0.86	0.51	43.1	89.7
Diastolic dysfunction of left ventricle	0.48	0.73	43.7	76.9

So, this research has confirmed the results we had previously obtained, in this case, LVEF had the greatest connection with complications development. For the purpose of estimating predictive value, sensitivity and specificity levels were determined for each of the prognostic parameters. As a result of performed analyses, AMI was determined as having the highest sensitivity (0.92), and the presence of LVDD of the heart presented the highest specificity (0.73) (Table 2).

So we have noted that the presence and severity stage of MR remains one of the important predictors of complications development in the early CABG post-operative period.

Discussion

According to the numerous researches data, the main cause of death in patients having undergone myocardial revascularization is AHF, due to systolic or diastolic myocardial dysfunction.[10] So, according to Ushakov[5] perioperative predictors of acute heart failure development are: 1) value of the scale of the complex evaluation of age degree of wear (AHF = 1.2; p = 0.001); 2) Systolic LV dysfunction in the presence of EF less than 50% (AHF = 9.0; p = 0.001); 3) AC using (AHF = 1.1; p = 0.036).

Some authors have demonstrated the dependence of the development of the complications on age,[11] but this is not the single opinion. Sumin et al. haven't found such dependence.[12] We have noted that the age of patients did not have significant impact on the development of AHF during the intraoperative and early postoperative periods. However, the most number of authors tend to conclude the older people (especially those older than 80 years) had a higher risk of death and serious complications.[13] Like the research of Gratti et al.[6] They have declared the hospital mortality in the period of 62±4 years was 5.3%. Fretschner et al.[8] have observed 1013 after CABG surgery and noted that women older than 60 years, patients who suffered two or more myocardial infarctions, who had previously been in intensive care, had oxygen saturation of less than 70%, and needed three or more shunts for complete revascularization had the highest risk of lethal outcome development.

If we are looking for echocardiographic indicators we can say about AMI in anamnesis and immediately prior to CABG were the factors of the highest risk of postoperative complications. Our data is supported also by researches of other authors.[14–16] The risk of complications development in case of CABG increases if the AIM has been presented in anamnesis, an intraoperative connection of intra-aortic balloon counterpulsation has been conducted; the artificial circulation has been used for more than 120 min, and aortic compression has been introduced for more than 90 min.[12]

We have got data opposite[17] to the one declared by Nadeem et al. and Ortiz et al. that length of the artificial circulation period and aortic compression time are the predictors of postoperative complications development in cardiac surgical patients.[18,19]

Our research has shown there is no significant influence of the number of applied shunts on the complications development. Other researchers demonstrated the number of bypass shunts (of two or more) is a risk factor of complications development in patients after CABG.[20]

The hospitalization length is considered by the number of researchers as an indicator of complicated course of postoperative period.[21] But we have not found such dependence.

As our earlier researches showed, LVEF, DDLV stage, and MR out of echocardiographic indicators had the closest dependence related to cardiac complications development.[22] Other echocardiographic indicators, like heart size, IVS thickness, and LVPW, didn't show such dependence.

Vic Kneson et al.[7] performed retrospective analyses of 346 patients (2015–2019) with low LVEF (≤30%). Results of observations have showed patients with significant LV dysfunction, subjected to CABG, were satisfactory for a month. The most significant predictors of mortality were hemodynamic instability and renal dysfunction. Khaled et al.[23] have shown patients with diabetes mellitus, with significant diastolic LV dysfunction, and after using the intra-aortic counterpulsation in surgery had increased risk of hospital lethality.

Conducted research has confirmed the results we had previously obtained, in this case, LVEF had the greatest connection with complications development. Data of literature have also shown that LVEF is the most significant risk factor of serious complications developed during the early postoperative period.[9,16]

Gratti et al.[6] studied 4383 cases after CABG performed because of multiple coronary artery lesions (January 1999 September 2014; the average age of 300 studied patients – 66.1±9.6 years). The most frequent postoperative complications were prolonged invasive ventilation (17.7%) and acute renal failure (14.7%).

Data of other researchers showed[24] that people who had undergone CABG surgery complicated by CF, have increased mortality risk developing in the late (within a year) postoperative period. Risk of AHF development after CABG is increasing with coronary artery lesions (more than 4 coronary arteries), long time of surgery, and reconstruction of LV cavity in the case of its aneurysm.[20] The risk of CABG complications development increased if:

1) MI with unstable hemodynamics/shock up to 24 hours;
2) acute coronary syndrome is present;
3) the stenosis of the left coronary artery trunk has been diagnosed;
4) LVEF was ≤ 35%.[12]

The most frequent development of threatening perioperative complications (pulmonary artery thromboembolism, acute cerebral circulation disorder, AHF, ventricular fibrillation, intraoperative MI) occurs when performing CABG up to 10 days from the moment of AMI development.[25]

In recent years LVDD has received greater attention. It has been proved that during the post-perfusion period LVDD can be due to ischemic and reperfusion damage, hypothermia, metabolic disorders, or myocardial edema and is the independent factor in

the development of difficulties in excommunicating the patient from AC, using high doses of inotropic support and increased risk of complications development.[10] LVDD has been shown to be powerful, predisposing factor in the development of postoperative atrial fibrillation. It was established, LVDD increases preoperative mortality in patients with cardiac surgical profiles.[25] LVDD has also been shown as an independent risk factor for postoperative CF, atrial fibrillation, and fatal outcome.[26]

MR presence together with IHD significantly increases mortality of such patients. So more than 40% of ill people with combined IHD and MR of severe stage die during the first year from the moment of MR.[27] If the combination of IHD and MR (moderate stage) is present, mortality is about 15–18%; if MR is in the mild stage 8–11%. At the same time, the mortality of patients with IHD without MR is 5% approximately.[28] It has been shown convincingly that moderate ischemic MR had affected the increased risk of mortality from cardiovascular diseases, including patients with CF.[29] Our data confirm that presence and severity stage of MR remains one of the important predictors of complications development in the early CABG post-operative period.

Study limitations

All conducted observations were made in conditions of the private cardiology clinic. The observation results can depend on the current condition of the certain conditions of the hospital and surgeons' qualifications and the number of surgeries for the year. So, each clinic has to have its own research on the occurrence of the complications' predictors.

Conclusions

Results of our researches, performed in the current conditions of the private clinic, showed that, unlike data from other clinics, such parameters as age of patients, length of artificial circulation period, and the time of aortic compression, as well as the number of applied shunts did not show the statistically significant effect on the development of complications. This supports our proposal to identify predictors of the development of complications following coronary artery bypass grafting surgery in each separate clinic.

The closest connection of complications development during the intraoperative and early postoperative periods in the considered clinic was revealed with acute myocardial infarction, with low left ventricular ejection fraction, and the presence of diastolic dysfunction of left ventricular. In this case acute myocardial infarction had the most sensitivity on development, and the presence of diastolic dysfunction of left ventricular had the greatest specificity.

Conflict of interest
There are no conflicts of interest in the presented research.

Authors' information and contribution
Damir Osmonov, PhD in Medicine (0000-0001-6715-722X), collected the study results and created Discussion section; **Asan Nazarov**, Head of the Cardiothoracic Surgery and Resuscitation Department, (0000-0002-6949-2678), collected and analyzed (processed) research data; **Mustafa Unal**, Cardiac Surgeon, (0000-0002-1622-6923), collected the study results and created Discussion section; **Ishenbai Moldotashev**, Doctor in Medicine, Professor, (0000-0001-5525-3599), was the author of the study design, created Discussion section, and formed the conclusions of the research; **Nazaraly Usubaliev**, PhD in Medicine, Associate Professor, (0000-0002-8571-6803), created the Introduction and Discussion sections and formed the final article; **Alexander Sorokin**, PhD in Biology, (0000-0002-9682-8085), conducted and interpreted the results of statistical analysis, formed the Materials and Methods and Results parts of the Paper; **Dmitry Lezhnin**, Cardiac Surgeon, (0000-0001-9705-2891) has a part in data processing and results analyzing.

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