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Method for Evaluating the Risk of Cardiovascular Complications in Surgical Procedures

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Abstract **Original Research Article**

Cardiovascular disease (CVD) remains a leading cause of mortality, particularly among younger populations, necessitating advancements in surgical interventions such as coronary artery bypass grafting (CABG). This study assessed the likelihood of early postoperative complications in 121 CABG patients, categorizing them by intraoperative hemolysis (IOH) levels. Complications were observed in 23.6% of patients, with a significantly higher rate in those with severe ischemic organ damage (57.9%, $p<0.001$). Key predictors of complications included oxidative stress markers, free iron levels, and endothelial dysfunction. A predictive model integrating biochemical parameters such as malondialdehyde, transferrin, and nitric oxide metabolites demonstrated high sensitivity (96.5%) and specificity (100%), with an area under the ROC curve of 0.992. These findings highlight the importance of early risk assessment, oxidative stress management, and individualized treatment strategies to enhance postoperative outcomes. Future research is essential to validate and implement these predictive methods in clinical practice.

Keywords: Coronary Artery Bypass Grafting, Complications, Ischemic Heart Disease, Early Period,

Relevance. Cardiovascular disease (CVD) is increasingly affecting younger populations, particularly among men and individuals of working age, making it a significant concern in the realm of surgical intervention. In Belarus, over 70,000 individuals succumb to CVD each year, highlighting the urgent need for effective treatment strategies. Given the high prevalence of cardiovascular conditions contributing to morbidity, disability, and mortality rates, there has been substantial advancement in cardiac surgical procedures. This trend emphasizes the importance of addressing CVD through surgical means, as it plays a crucial role in improving patient outcomes and reducing the burden of this disease on society. The rising incidence of CVD among younger demographics necessitates ongoing research and innovation in surgical techniques and postoperative care to enhance survival rates and quality of life for affected individuals. Cardiovascular pathology accounts for approximately 2/3 of deaths from CVD [1].Worldwide, cardiovascular pathology accounts for 12.2% (7.2 million people) in the structure of mortality [2] However, the outcome of CABG surgery is fraught with various complications of cardiovascular genesis, including those that pose a threat to the patient's life. According to Russian authors, complications develop in 68% of patients who have undergone CABG [3]. Performing reconstructive surgeries (stenting, coronary bypass, balloon angioplasty) in patients with cardiac pathology, the presence of concomitant diseases and a number of risk factors determine the possibility of complications, including fatal ones. One of the mechanisms for the development of complications after CABG is reperfusion syndrome, which is a

complex of disorders in the myocardium after the restoration of blood flow in it. The mechanisms are oxidative stress, inflammation, energy deficiency, edema, apoptosis. The use of CB, in the contours of which conditions for hemolysis are created, revealed the involvement of free hemoglobin and iron, as well as oxidative and nitrosative stress in the mechanisms of complications of CABG surgery [5, 6].

The aim of the work was to develop a method for assessing the likelihood of complications of CABG in patients with ischemic heart disease in the early period.

Research methods. Patients undergoing CABG (n=121) were divided into three groups based on the degree of intraoperative hemolysis, IOH, determined by the level of free hemoglobin (Hbfree) in the blood plasma – [Hbfree] at the end of CABG surgery using the HemoCue Plasma/Low Hb analyzer (Sweden) [Omar H.R. et al., 2015, Pan K.C., 2016]: patients with coronary artery disease (stable angina, functional class II-IV) who underwent CABG, without IOH (n=43), low IOH – lIOH (n=42), high IOH – hIOH (n=38). Clinical, biochemical and statistical research methods were used. General clinical (ECG, CAG, ECHO-CG, blood pressure and pulse profile) and laboratory examination (OAC and OAM, BAC (lipidogram, proteinogram, C-reactive protein, residual nitrogen indicators (creatinine, urea)) were performed upon admission (before surgery) and within 5-7 days after surgery. The indicators of the transport and deposited pool of iron (serum iron, ferritin (F), transferrin (Tr), total and latent iron-binding capacity of the blood); stable metabolites of nitric oxide - [NOx], indicators of oxidative stress: malondialdehyde, MDA; diene conjugates, α-tocopherol, retinol; free hemoglobin level [Hbfree] (HemoCue Plasma/Low Hb, Sweden) were studied. The obtained data were analyzed by nonparametric statistics methods using the Statistica program 10.0 for Windows (StatSoft, Inc., USA), SPSS programs and R programs using the Boruta module.

Results and discussion. In a study involving 123 patients diagnosed with coronary heart disease who underwent coronary artery bypass grafting (CABG), cardiovascular complications of varying severity were observed in 29 patients, accounting for a complication rate of 23.6%. The specific complications included arrhythmias, which were noted in 27 patients (21.95%) and comprised atrial fibrillation, paroxysms of ventricular tachycardia, as well as supraventricular and ventricular extrasystoles. Progression of heart failure, indicated by a decrease in ejection fraction, was observed in 13 patients (9.8%). Additionally, myocardial infarction occurred in 5 patients (4.1%), and stroke was documented in 2 patients (1.6%). A significant finding of this study was the markedly higher incidence of complications in the group identified with ischemic organ damage (hIOH), where complications were observed in 57.9% of the patients ($p<0.001$). In contrast, the group without ischemic organ damage (lIOH) exhibited a complication rate of only 11.9% ($p<0.001$), while the group without any ischemic organ damage showed a notably lower rate of 4.7% ($p<0.001$). The EuroScore II risk assessment indicated that the highest risk levels were found in the hIOH group. The characteristics of the EuroScore II model for predicting complications included a modified Hosmer-Lemeshow statistic ($\chi^2=2.310$; $p=0.970$), with a sensitivity of 50% and a specificity of 98.8%. The area under the receiver operating characteristic (ROC) curve was calculated to be 0.639 (95% CI: 0.394-0.884), indicating moderate predictive capability. To enhance the assessment of early postoperative complications, a logistic regression analysis was performed using the SPSS software and the Boruta module. This analysis led to the development of a statistical model based on biochemical parameters, specifically malondialdehyde (MDA), transferrin, and ΔNOx levels. The results indicated that a calculated probability value (p) of ≥0.54 in patients with coronary artery disease post-CABG was associated with a high risk of developing early complications. The quality assessment of this multiple logistic regression model yielded favorable results, as indicated by the Hosmer-Lemeshow statistic (χ^2 = 11.1; $p=0.194$). The sensitivity of this predictive method was remarkably high at 96.5%, with a specificity of 100%. The positive predictive value (PPV) was also 100%, while the negative predictive value (NPV) reached 98.9%. Furthermore, the area under the ROC curve for this model was exceptionally high at 0.992 (95% CI: 0.832-0.998),

demonstrating its excellent performance in predicting early complications following CABG. Findings underscore the importance of identifying high-risk patients through both clinical and biochemical assessments to enhance postoperative management and potentially improve outcomes for individuals undergoing CABG surgery.

Conclusions

1. Importance of Early Diagnosis

Early identification of patients at high risk for complications after CABG allows for more targeted preventive measures. Utilizing the proposed method alongside EuroScore II may enhance predictive accuracy and subsequently improve the quality of medical care.

2. Assessment of Oxidative Stress Markers

Indicators characterizing oxidative stress activity can serve as important predictors of complications. Incorporating these markers into clinical practice may aid in timely correction of metabolic disturbances and improve postoperative outcomes.

3. Correction of Free Iron Levels

The level of free iron is a significant indicator that may influence the risk of thrombosis and other complications. Regular monitoring and correction of this parameter could reduce the risk of postoperative complications.

4. Maintenance of Endothelial Function

Endothelial health plays a crucial role in vascular function. Implementing therapeutic strategies aimed at improving endothelial function, such as the use of antioxidants or agents that enhance microcirculation, may be beneficial in the postoperative period.

5. Individualized Treatment Approach

Each patient is unique, and their response to surgery can vary. The application of the proposed method allows for the development of individualized treatment and prevention plans, contributing to more effective management of patient conditions.

6. Need for Further Research

While the results are promising, additional clinical trials are necessary to validate the effectiveness of the proposed method. This will help establish its reliability and applicability across different patient populations.

7. Implementation in Clinical Practice

Successful implementation of the new method in clinical practice requires training for medical personnel and the development of protocols based on the obtained data. This will ensure a higher level of physician preparedness and enhance patient care quality.

8. Multidisciplinary Approach

Preventing complications after CABG should be part of a multidisciplinary approach involving cardiologists, surgeons, anesthesiologists, and other specialists. This will provide comprehensive management of patient conditions and improve treatment outcomes.

9. Long-term Consequences

It is essential not only to focus on the early postoperative period but also to assess long-term consequences of the intervention. Monitoring patients for a year or more post-surgery will help identify late complications and adjust treatment accordingly.

10. Economic Efficiency

Implementing the proposed method may lead to reduced treatment costs due to fewer complications and readmissions. This is crucial for healthcare systems aiming to optimize resources and improve access to quality medical care.

These conclusions can help emphasize the significance of the study and the proposed method, as well as its potential to enhance the quality of care

for patients following coronary artery bypass grafting.

ABBREVIATIONS:

CABG: coronary artery bypass grafting
IOH: intraoperative hemolysis
NO_x: nitric oxide metabolites
MDA: malondialdehyde
ROC: receiver operating characteristic
CAD: coronary artery disease
ECG: electrocardiography

Conflict of Interest: The authors declare that there are no conflicts of interest

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