

Research Article

Predicting of Early Cardiovascular Complications After Coronary Artery Bypass Graft Surgery

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Abstract

Reconstructive heart surgeries, like coronary artery bypass grafting (CABG), carry a risk of significant complications, including death. These complications encompass a range of cardiovascular issues, including CABG-related myocardial infarction, worsening heart failure, arrhythmias. This study aimed to develop a method for predicting these early postoperative complications in patients undergoing CABG. The prediction model was based on the relationship between hemolysis, changes in iron levels, markers of oxidative stress, and nitric oxide levels. The study's approach draws upon earlier investigations, which looked at the relationship between complications following CABG and: intraoperative hemolysis, changes in iron transport and storage, oxidative stress levels, and stable nitric oxide metabolites. This research built on that foundation to create a more comprehensive understanding and prediction method. This study employed a multi-faceted approach to investigate the relationship between intraoperative hemolysis and the development of early postoperative cardiac complications after CABG. A total of 123 patients with coronary artery disease (CAD), who underwent CABG, were categorized into three groups based on the degree of IOH, measured by free hemoglobin (Hb) levels in blood plasma at the conclusion of the CABG procedure using a Hemo Cue Plasma/Low Hb analyzer. Groups were: no significant intraoperative hemolysis (n=43), low intraoperative hemolysis (n=42), and high intraoperative hemolysis (n=38).

Keywords

Bypass Grafting, Oxidative, Complications, Iron, Nitric Oxide, Hemolysis

1. Relevance

The study enrolled 123 patients undergoing coronary artery bypass grafting (CABG). Patients were categorized into three groups based on the degree of intraoperative hemolysis (IOH). Blood samples were collected pre- and post-operatively to assess various parameters related to iron metabolism, oxidative stress, and nitric oxide [1]. These included indicators of iron transport (serum iron, transferrin, total and latent iron-binding capacity), iron storage (ferritin) [2], nitric oxide metabolites (NO_x) [3], and oxidative stress markers

(malondialdehyde (MDA), diene conjugates, α -tocopherol, and retinol) [4]. Using statistical analyses (multiple logistic regression and receiver operating characteristic (ROC) curve analysis), the researchers found that levels of MDA, transferrin, and NO_x were significantly associated with the development of early postoperative complications. Critically, the study observed a strong correlation between the severity of intraoperative hemolysis and the rate of complications [5]. The high hemolysis group exhibited a substantially higher

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incidence of complications (57.9%) compared to the low hemolysis group (11.9%) and the no hemolysis group (4.7%). The proposed method offers a valuable tool for predicting early postoperative complications in patients undergoing CABG for IHD [6]. The predictive model incorporates MDA, NO_x, and transferrin levels. These markers reflect oxidative stress, free iron levels, and potentially, endothelial dysfunction – all factors implicated in the development of post-operative complications [7-9]. This predictive capability can assist in making timely decisions regarding patient management, potentially enabling the implementation of preventative measures or specific interventions to address oxidative processes and endothelial dysfunction in high-risk individuals. This study investigated the early cardiac complications that can arise after CABG surgery in patients with coronary artery disease [10]. Previous research has explored the link between the frequency of these complications and factors such as the degree of intraoperative hemolysis (blood breakdown during surgery), changes in iron metabolism, oxidative stress levels, and nitric oxide metabolites.

The primary goal of this research was to develop a method for predicting the probability of developing cardiovascular complications in the early postoperative period following CABG. The prediction method focuses on how changes in iron levels, oxidative stress, and nitric oxide levels are influenced by the degree of intraoperative hemolysis. The researchers aimed to identify indicators that could be used to anticipate the risk of these complications. The study's approach draws upon earlier investigations, which looked at the relationship between complications following CABG and: intraoperative hemolysis [11], changes in iron transport and storage [12], oxidative stress levels, and stable nitric oxide metabolites [13]. This research built on that foundation to create a more comprehensive understanding and prediction method. This study employed a multi-faceted approach to investigate the relationship between intraoperative hemolysis and the development of early postoperative cardiac complications after CABG.

2. Research Methods

A total of 123 patients with coronary artery disease (CAD), who underwent CABG, were categorized into three groups based on the degree of IOH, measured by free hemoglobin (Hb) levels in blood plasma at the conclusion of the CABG procedure using a Hemo Cue Plasma/Low Hb analyzer. Groups were: no significant intraoperative hemolysis (n=43), low intraoperative hemolysis (n=42), and high intraoperative hemolysis (n=38). Comprehensive clinical evaluations were conducted, including electrocardiography (ECG), coronary angiography, echocardiography, and monitoring of blood pressure and pulse. Biochemical analyses of blood samples were performed before surgery and within 5-7 days post-surgery. These analyses included a complete blood count, complete urinalysis, lipid profile, protein profile, C-reactive

protein, and levels of residual nitrogen (creatinine and urea). The researchers meticulously tracked cardiac complications during the first month after surgery (including the perioperative period), specifically noting myocardial infarction, stroke, arrhythmias, and death. Assessment of iron metabolism, nitric oxide, and oxidative stress: blood samples were collected from the cardiopulmonary bypass machine at the start and end of the CABG procedure to evaluate various markers. These markers included indicators of iron transport (serum iron, transferrin, total and latent iron-binding capacity), iron storage (ferritin), nitric oxide metabolites (nitrite/nitrate ions [NO_x]), and oxidative stress parameters (malondialdehyde, diene conjugates, α-tocopherol, and retinol) [14]. The collected data were analyzed statistically using non-parametric methods in the Statistica 10.0 software package. The researchers also employed logistic regression analysis within the R programming environment, utilizing the Borute package to identify significant predictors of cardiac complications [15].

3. Results and Discussion

123 of the patients examined with ischemic heart disease and coronary artery bypass grafting, cardiovascular complications of varying severity were observed in 29 (23.6%) patients: arrhythmia (atrial fibrillation, paroxysms of ventricular tachycardia, supraventricular and ventricular extrasystoles) in 27 patients (21.95%), progression of heart failure (decrease in ejection fraction) in 13 patients (9.8%), myocardial infarction in 5 patients (4.1%), acute cerebrovascular accident in 2 patients (1.6%). The highest incidence of complications was observed in the group with high IOH (p<0.001) – 57.9%, which is more than in the group with low IOH – in 11.9% of patients (p<0.001) and in the group without IOH – in 4.7% of operated patients (p<0.001) [4].

Based on the analysis, a formula was obtained for assessing the probability (p) of complications after CABG surgery, which has the general form:

$$p = \frac{1}{1 + \exp^{-(b_0 + b_1 \times X_1 + b_2 \times X_2)}} \quad (1)$$

where: exp is the base of the natural logarithm (exp = 2.718);

$z = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3$,

b_0 is the free term (intercept);

b_1, b_2, b_3 – logistic regression coefficients

X_1, X_2, X_3 – values of the variables [MDA], [Δ NO_x] and [Tr] selected in the equation, respectively.

As a result,

$z = 0.799 \times [\text{MDA}] + 0.192 \times [\Delta\text{NO}_x] - 0.062 \times [\text{Tr}]$, where [MDA] is the concentration of malondialdehyde in blood plasma, μm/l;

[Δ NO_x] is the difference between the 2-nd and 1st samples of nitrate/nitrite levels in blood plasma, μmol/l;

[Tr] is the level of transferrin in blood plasma, mg/dl.

As a result, the equation for determining the probability of developing complications after CABG surgery took the following form:

$$\rho = \frac{1}{1 + \exp^{-(0.799 \times [\text{MDA}] + 0.192 \times [\Delta \text{NO}_x] - 0.062 \times [\text{Tr}])}} \quad (2)$$

With a calculated value of $p \geq 0.54$, patients with coronary artery disease after CABG are at high risk of developing complications in the early period.

Assessments of the quality of the multiple logistic regression model: Hosmer-Lemeshow test ($\chi^2 = 11.1$; $p = 0.194$); the sensitivity of the method is 96.5%, the specificity is 100%, the PPV (positive predictive value) = 100%, the NPV (negative predictive value) = 98.9%, the area under the ROC curve (AUC) = 0.992. The odds ratio (OR) for MDA = 2.22, for ΔNO_x – 1.21, for Tr – 0.94.

Based on the results obtained using the multiple logistic regression method and ROC analysis, the possibility of using the values of MDA, transferrin (Tr), changes in nitrites and nitrates (NO_x) in the blood plasma in assessing the risk of complications of CABG surgery in the early period is shown. The use of MDA and NO_x indicators in the model reflects the relationship of CABG complications with the development of oxidative and nitrosative stress, while the transferrin level indirectly reflects the involvement of free iron in the mechanisms of complication development. The revealed dependence of the occurrence of complications on changes in these indicators in the blood plasma is consistent with the literature data on the development of heart failure under oxidative and nitrosative stress.

4. Conclusions

1. A statistical model for assessing the likelihood of developing cardiac complications in the early period in patients with coronary heart disease after CABG has been obtained, which involves determining malondialdehyde, changes in stable metabolites of nitric oxide and transferrin in the blood plasma of operated patients.
2. The proposed method allows determining the risk of developing cardiovascular complications in patients with coronary heart disease after CABG in the early period, based on the values of indicators characterizing the activity of oxidative stress, the level of free iron, the degree of endothelial dysfunction, which is important for timely management decisions.
3. The possibility of predicting the development of complications in high-risk patients suggests, along with generally accepted therapeutic measures, supplementing them with correction of the activity of oxidative processes and endothelial dysfunction.
4. The proposed method has high sensitivity and specificity, and therefore can be recommended for use in practical healthcare to predict CABG complications in patients

with coronary heart disease in the early period, which will reduce the likelihood of their development by carrying out therapeutic and preventive measures in the intra- and postoperative periods.

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

Author Contributions

Maksimovich Yelizaveta is the sole author. The author read and approved the final manuscript.

Conflict of Interest

The author declares no conflicts of interest.

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