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Article

Analysis of Risk Factors of Postoperative Arrhythmia in Patients with Coronary Heart Disease and Establishment of Nomogram Risk Model

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Abstract

Background: To explore the risk factors of postoperative arrhythmia in patients with coronary heart disease (CHD) and to establish a Nomogram model for predicting the risk of postoperative arrhythmia in CHD patients. **Methods**: Retrospectively, the medical data of CHD patients (from January 2021 to January 2024, n = 390) were collected. According to whether arrhythmia occurred after percutaneous coronary intervention surgery, patients were divided into the arrhythmia group (n = 130) and non-arrhythmia group (n = 260). The risk factors of postoperative arrhythmia were obtained by multi-factor logistic regression analysis. A Nomogram model for predicting the risk of postoperative arrhythmia in CHD patients was established using R language and underwent verification. **Results**: The results of multi-factor logistic regression analysis showed that diastolic pressure, heart function grade at III–IV, creatinine, C-reactive protein (CRP), N-terminal pro-brain natriuretic peptide (NT-ProBNP) peak value, total bilirubin (TBIL) and red cell distribution width (RDW) were the risk factors inducing postoperative arrhythmia in CHD patients. Based on these risk factors, a Nomogram model was successfully established. The verification results revealed that the predicted values were basically consistent with the actual values, indicating that the Nomogram model had good prediction ability. The area under the curve (AUC) value was 0.974, suggesting the high prediction efficiency of Nomogram model. **Conclusion**: Diastolic pressure, heart function grade at III–IV, creatinine, CRP, NT-ProBNP peak value, TBIL and RDW are the risk factors of postoperative arrhythmia in CHD patients. Nomogram model based on these risk factors has good prediction efficiency and underlying clinical value.

Keywords

coronary heart disease; postoperative arrhythmia; logistic regression analysis; risk factor; Nomogram model

Introduction

Coronary heart disease (CHD), a common cardiac disease, is highly responsible for death and disability from cardiovascular diseases in the world [1]. As the third lethal factor globally, CHD is related to 17.8 million deaths every year [2]. In recent years, with the aging of population in China, the incidence and mortality of CHD are on the rise, especially in rural areas [3,4]. Fortunately, some therapeutic measures have been developed; for instance, percutaneous coronary intervention (PCI) surgery [5,6] which has been confirmed to improve CHD [7]. Nevertheless, various complications after PCI surgery, such as malignant ventricular arrhythmia and cardiac arrest, can result in a high mortality in CHD patients [8], which become a hard nut to crack in clinical practice. Among them, arrhythmia is a common complication with highly fatal risk.

Reportedly, the arrhythmia mainly includes persistent ventricular tachycardia (VT), ventricular fibrillation (VF) and ventricular flutter, easily causing chronic heart failure [9]. After PCI surgery, CHD patients with arrhythmia encounter a higher mortality than CHD patients without arrhythmia [10]. Therefore, monitoring cardiac function is essential during the perioperative period. However, the mechanism of postoperative arrhythmia in CHD patients has not been deciphered. The occurrence of postoperative arrhythmia in CHD patients is closely associated with old age, high creatinine level, low left ventricular ejection fraction (LVEF), essential hypertension and re-operation [11]. Yet, the related risk factors have not been completely discovered.

In this study, we retrospectively collated the medical data of CHD patients with and without postoperative arrhythmia, carrying out a systematical analysis to exhibit an objective report. We further dissected more independent risk factors involved in the occurrence of postoperative arrhythmia in CHD patients. Based on these risk factors, a Nomogram model was established to predict the risk of postoperative arrhythmia in CHD patients, which could provide a reference for the clinical prevention and treatment of postoperative arrhythmia.

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Methods

Sample Size

Considering the small number of samples about ventricular arrhythmia in the hospital, this study adopted a case-control sample size of 1:2. Herein, ventricular arrhythmia was mainly represented by VT. When the ejection fraction was decreased, the probability of VT was 32.61% [12]. Moreover, the odds ratio between ejection fraction decrease and arrhythmia occurrence was 2.953 [13]. The sample size was calculated by PASS 15.0 software (NCSS Inc., Kaysville, UT, USA). Parameters were as follows: power = 90%; α = 0.05; sample shedding rate = 5%; R^2 = 0.5. Finally, based on calculation, the required sample size of arrhythmia group was at least 130 cases, and that of non-arrhythmia group was at least 260 cases. Therefore, a total of 390 samples were included in this study.

Research Design

In this study, the medical data of CHD patients (from January 2021 to January 2024, n = 390) were retrospectively collected, who have undergone PCI 6 months or more earlier. This research was approved by the Ethical Committee of Qingdao Municipal Hospital (Group) (the ethics approval number: 2024-LW-042) and in accordance with the declaration of Helsinki. And all patients have signed informed consent.

Diagnosis, Inclusion and Exclusion Criteria

Postoperative arrhythmias are defined as VT, VF, and premature ventricular beats that occur immediately or within 24–48 hours after surgery. Diagnosis criteria for the arrhythmia [14]: (1) arrhythmia belongs to persistent VT (heart rate $\geq$120 beats/min, and $\geq$3 consecutive ventricular beats), VF (the QRS wave is unrecognizable and presents irregular electrocardiogram (ECG) waveform) and veatricular flutter; (2) the electrocardiograph monitoring of the course record suggested the persistent VT, VF or ventricular flutter; (3) course of disease/nursing course revealed that antiarrhythmic drugs should be used for cardioversion or defibrillation and primary cardiopulmonary resuscitation due to persistent VT, VF or ventricular flutter.

Inclusion criteria: (1) received history of percutaneous coronary intervention (PCI) surgery; (2) normal consciousness level; (3) use of drugs according to the guidelines after PCI surgery; (4) the patient had no clear history of arrhythmia before hospital.

Exclusion criteria: (1) incomplete clinical information; (2) other serious heart diseases, such as fulminant myocarditis, dilated cardiomyopathy and hypertrophic cardiomyopathy; (3) malignant tumor, severe liver and kidney dysfunction, autoimmune diseases and other diseases that obviously affects the prognosis of patients; (4) serious infection, trauma or major surgery before PCI surgery; (5) during pregnancy or lactation; (6) use of anti-arrhythmic medication before hospitalization.

The Timing of Revascularization Therapy

ST-elevation myocardial infarction (STEMI) patients:

Current domestic and international guidelines recommend direct PCI as the preferred strategy of reperfusion therapy in patients with STEMI [15], and PCI is directly recommended for STEMI patients treated within 12 h of the onset of the disease. However, PCI is also reasonable for stable patients who seek treatment 12 to 24 hours after onset.

For patients with non-ST-segment elevation acute coronary syndrome (NSTE-ACS):

High-risk patients and those with recurrent ischemic attacks should receive invasive treatment immediately or as soon as possible (within 24 hours). The guidelines recommend that for low-risk patients, invasive treatment may be appropriately delayed after hospital admission is stable.

Patients with stable angina:

Coronary artery examination can be completed according to the patient's condition.

Grouping

According to whether arrhythmia occurred after PCI surgery, 390 CHD patients were assigned into the arrhythmia group (n = 130) and non-arrhythmia group (n = 260). Then, the medical data of CHD patients in both groups were analyzed.

Collection and Analysis of Clinical Data

Baseline Characteristics

The baseline data of CHD patients were acquired from their medical records, including gender (male or female), age, smoke (yes or no), drink (yes or no), primary hypertension (yes or no), diabetes (yes or no), hyperlipidemia (yes or no), chronic nephrosis (yes or no) and heart disease course (<10 years or $\geq$10 years). The course of heart disease refers to the length of the history of coronary heart disease, which is calculated from the diagnosis of coronary heart disease.

Cardiac Indicators

In line with CHD patients' medical records, the cardiac indicators on admission mainly included the history of cardiac surgery (yes or no), heart rate, systolic pressure, diastolic pressure, heart function grade (I, II, III or IV), LVEF, LVEF (<40% or $\geq$40%), criminal vessel (left anterior descending branch, left circumflex branch or right coronary artery), thrombolysis in myocardial infarction (TIMI) blood flow grade (0–1, 2 or 3) and number of implanted stents (0, 1, 2 or ≥3).

Preoperative Serum Indicators

Based on CHD patients' medical records, the preoperative serum indicators were mainly composed of the kalium, natrium, calcium, preoperative blood glucose, creatinine, white blood cells (WBC), C-reactive protein (CRP), D-dimmer, fibrinogen (FIB), total cholesterol (TC), triglyceride (TG), high density lipoprotein-cholesterol (HDL-C), low density lipoprotein-cholesterol (LDL-C), high density lipoprotein (HDL), low density lipoprotein (LDL), N-terminal pro-brain natriuretic peptide (NT-ProBNP) peak value, total bilirubin (TBIL), glomerular filtration rate (GFR), red cell distribution width (RDW) and ratio of neutrophil/lymphocyte (NE/LY). Fasting venous blood (5 mL) was collected from each CHD patient in the morning. The levels of above serum indicators were detected by Mindray BS220 automatic biochemical analyzer (Nanjing Baden Medical, China).

Multi-Factor Analysis

The indicators with significant differences between groups were used for multi-factor (logistic regression) analysis to explore the independent risk factors of postoperative arrhythmia in CHD patients.

Establishment and Verification of the Nomogram Model

In light of the independent risk factors screened above, a Nomogram model for predicting the risk of postoperative arrhythmia in CHD patients was established and verified.

Statistical Analysis

SPSS 26.0 software (SPSS Inc., Chicago, IL, USA) was applied for statistical analysis. The continuity variables conforming to the normal distribution were described by mean ± standard deviation, which were compared by the independent sample *t* test between groups. The continuity variables not conforming to the normal distribution were expressed by quartile method [M (P_{25}–P_{75})], which were compared by Mann-Whitney *U* test between groups. Multi-factor analysis was performed using forward stepwise regression method based on maximum likelihood estimation for logistic stepwise regression analysis (α_{in} = 0.05, α_{out} = 0.10). Here were related assignment explanations. Dependent variable: arrhythmia = 1; non-arrhythmia = 0. Independent variable: heart function grade at I–II = 1; heart function grade at III–IV = 2. In other single-factor analysis, the independent variables of continuous data with $p < 0.05$ were directly inputted into the logistic regression model for analysis. The Nomogram model was established by R language (rms program package). R package was used for building receiver operator characteristic (ROC) curve. R package (version 4.3.2, RStudio, Houston, TX, USA) and other R packages (such as dplyr (https://github.com/tidyverse/dplyr) and ggplot2 (https://ggplot2.tidyverse.org)) were applied for data visualization. The significance level was defined by bilateral $p < 0.05$.

Outcomes

Baseline Characteristics

As displayed in Table 1, the mean age of the arrhythmia group (n = 130, including 106 males and 24 females) was 48.52 ± 13.82 years old and that of the non-arrhythmia group (n = 260, including 211 males and 49 females) was 44.42 ± 13.65 years old, which varied significantly between the two groups ($p < 0.05$). There was an apparent difference about the heart disease course between the two groups (Table 1, $p < 0.05$). In addition, there were insignificant differences between the arrhythmia group and the non-arrhythmia group in terms of gender, smoke, drink, primary hypertension, diabetes, hyperlipidemia and chronic nephrosis (Table 1, all $p > 0.05$).

Cardiac Indicators

Moreover, the cardiac indicators were compared between the arrhythmia group and the non-arrhythmia group. We found that heart rate, systolic pressure, diastolic pressure, heart function grade and LVEF were notably different between the two groups (Table 2, all $p < 0.05$), while the history of cardiac surgery, criminal vessel, TIMI blood flow grade and number of implanted stents were insignificantly different (Table 2, all $p > 0.05$).

Preoperative Serum Indicators

As for the preoperative serum indicators, our data revealed that the creatinine, WBC, CRP, D-dimmer, NT-ProBNP peak value, TBIL and RDW were greatly different between the arrhythmia group and the non-arrhythmia group (Table 3, all $p < 0.05$), but kalium, natrium, calcium, preoperative blood glucose, FIB, TC, TG, HDL-C, LDL-C, HDL, LDL, GFR and NE/LY were barely different (Table 3, all $p > 0.05$).

Multi-Factor Analysis

Furthermore, the multi-factor (logistic regression) analysis was performed to explore the risk factors of postoperative arrhythmia in CHD patients. Our data demonstrated diastolic pressure, heart function grade at III–IV, creatinine, CRP, NT-ProBNP peak value, TBIL and RDW as the risk factors for the occurrence of postoperative arrhythmia in CHD patients (Table 4, $p < 0.05$).

Table 1. Comparison of baseline characteristics.

Indicator	Arrhythmia (n = 130)	Non-arrhythmia (n = 260)	$t/Z/\chi^2$	p
Gender [n (%)]			0.008	0.927
Male	106 (81.54)	211 (81.15)		
Female	24 (18.46)	49 (18.85)		
Age (year)	48.52 ± 13.82	44.42 ± 13.65	2.789	0.006
Smoke [n (%)]			0.185	0.667
No	63 (48.46)	120 (46.15)		
Yes	67 (51.54)	140 (53.85)		
Drink [n (%)]			0.907	0.341
No	83 (63.85)	153 (58.85)		
Yes	47 (36.15)	107 (41.15)		
Primary hypertension [n (%)]			0.867	0.352
No	59 (45.38)	131 (50.38)		
Yes	71 (54.62)	129 (49.62)		
Diabetes [n (%)]			0.150	0.699
No	110 (84.62)	216 (83.08)		
Yes	20 (15.38)	44 (16.92)		
Hyperlipidemia [n (%)]			0.596	0.440
No	121 (93.08)	236 (90.77)		
Yes	9 (6.92)	24 (9.23)		
Chronic nephrosis [n (%)]			0.126	0.722
No	129 (99.23)	257 (98.85)		
Yes	1 (0.77)	3 (1.15)		
Heart disease course [n (%)]			5.278	0.022
<10 years	59 (45.38)	150 (57.69)		
≥10 years	71 (54.62)	110 (42.31)		

Establishment and Verification of the Nomogram Prediction Model

According to the multi-factor analysis results, a Nomogram prediction model was established (Fig. 1). The total score was 0–100 points, and the sum of the individual item scores of variable was calculated. The higher total score represented the greater risk of postoperative arrhythmia in CHD patients.

Additionally, we verified the Nomogram prediction model. As displayed in Fig. 2, the predicted values were basically consistent with the actual values about the occurrence of postoperative arrhythmia in CHD patients. A slope closer to 1 indicated that the model was well-calibrated, and accordingly the Nomogram model had good prediction ability. The area under the curve (AUC) value was 0.974 (95% CI: 0.959–0.989) (Fig. 3), implying that the Nomogram model had good discrimination.

Discussion

In clinical practice, it is still a challenge to determine the optimal intervention timing for CHD patients with postoperative arrhythmia. In this study, we established a systematic risk assessment system of related factors for postoperative arrhythmia in CHD patients. The early detection, prevention and treatment are beneficial to reduce the occurrence of major adverse cardiovascular events, alleviate economic pressure and improve long-term prognosis in CHD patients.

The related baseline characteristics, cardiac function parameters and serum factors in arrhythmia group and non-arrhythmia group are crucial indicators to reflect CHD patients' status, such as age, heart disease course, heart rate, systolic pressure, diastolic pressure, heart function grade, LVEF, creatinine, WBC, CRP, D-dimmer, NT-ProBNP peak value, TBIL and RDW [16–19]. Therefore, these indicators are systematically collected and analyzed in this study, and our data unveiled obvious differences about these indicators between groups. Above abnormal factors may serve as predictive indicators of postoperative arrhythmia in CHD patients.

Arrhythmia is one of the common complications after PCI surgery in CHD patients [20]. At present, it is considered that the pathophysiological basis of arrhythmia after PCI surgery is complex, chiefly including the cardiac electrophysiological state, the change of myocardial microenvironment caused by blood flow occlusion and postoperative electrolyte disorder [21–23]. The severe arrhythmia after PCI surgery with poor therapeutic effect is often closely related to the obvious decline of cardiac function [24]. In this study, we further analyzed the risk factors of postoper-

Table 2. Comparison of cardiac indicators.

Indicator	Arrhythmia (n = 130)	Non-arrhythmia (n = 260)	$t/Z/\chi^2$	p
History of cardiac surgery [n (%)]			0.021	0.884
No	122 (93.85)	243 (93.46)		
Yes	8 (6.15)	17 (6.54)		
Heart rate (bpm)	85.00 (78.00, 96.75)	82.00 (74.00, 93.00)	–2.199	0.028
Systolic pressure (mmHg)	115.81 ± 16.64	120.35 ± 17.53	–2.450	0.015
Diastolic pressure (mmHg)	71.82 ± 10.48	78.40 ± 13.13	–5.356	<0.001
Heart function grade [n (%)]			62.159	<0.001
I	1 (0.77)	6 (2.31)		
II	34 (26.15)	173 (66.54)		
III	95 (73.08)	81 (31.15)		
IV	0 (0.00)	0 (0.00)		
LVEF (%)	66.04 (46.41, 71.36)	68.50 (62.58, 72.61)	–2.407	0.016
LVEF [n (%)]			6.516	0.011
<40%	27 (20.77)	29 (11.15)		
≥40%	103 (79.23)	231 (88.85)		
Criminal vessel [n (%)]			2.009	0.366
Left anterior descending branch	63 (48.46)	144 (55.38)		
Left circumflex branch	11 (8.46)	23 (8.85)		
Right coronary artery	56 (43.08)	93 (35.77)		
TIMI blood flow grade [n (%)]			1.901	0.387
0–1	122 (93.85)	233 (89.62)		
2	2 (1.54)	7 (2.69)		
3	6 (4.62)	20 (7.69)		
Number of implanted stents [n (%)]			4.821	0.185
0	15 (11.54)	14 (5.38)		
1	87 (66.92)	184 (70.77)		
2	25 (19.23)	56 (21.54)		
≥3	3 (2.31)	6 (2.31)		

Abbreviation: LVEF, left ventricular ejection fraction; TIMI, thrombolysis in myocardial infarction.

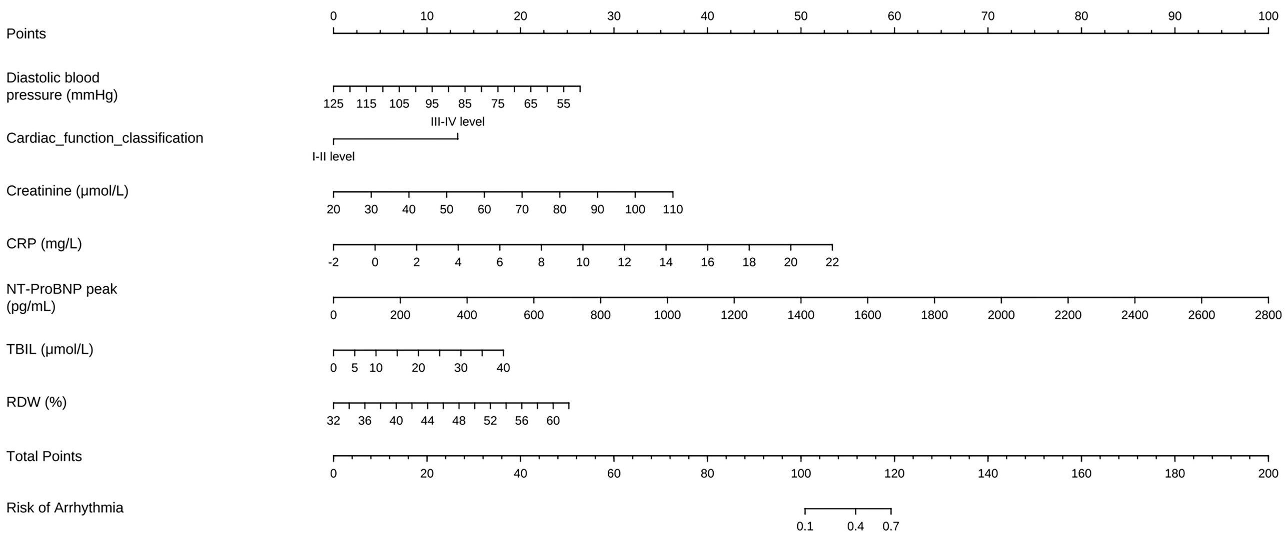

Fig. 1. Nomogram prediction model for predicting the risk of postoperative arrhythmia in CHD patients. Abbreviation: CRP, C-reactive protein; NT-ProBNP, N-terminal pro-brain natriuretic peptide; TBIL, total bilirubin; RDW, red cell distribution width.

Table 3. Comparison of preoperative serum indicators.

Indicators	Arrhythmia (n = 130)	Non-arrhythmia (n = 260)	*t/Z*	*p*
Kalium (mmol/L)	3.94 ± 0.29	3.98 ± 0.34	–0.992	0.322
Natrium (mmol/L)	139.57 ± 2.45	139.25 ± 2.18	1.310	0.191
Calcium (mmol/L)	2.21 ± 0.45	2.17 ± 0.37	0.870	0.385
Preoperative blood glucose (mmol/L)	5.04 ± 0.47	5.02 ± 0.48	0.313	0.755
Creatinine (μmol/L)	75.25 ± 12.70	66.79 ± 12.62	6.225	<0.001
WBC (10^9/L)	12.13 (10.89, 13.75)	9.68 (8.39, 11.26)	–9.740	<0.001
CRP (mg/L)	10.48 ± 4.32	6.18 ± 2.30	10.626	<0.001
D-dimmer (mg/L FEU)	0.44 (0.33, 0.55)	0.31 (0.21, 0.40)	–7.467	<0.001
FIB (g/L)	2.77 ± 0.59	2.71 ± 0.49	1.047	0.296
TC (mmol/L)	4.27 ± 0.72	4.32 ± 0.60	–0.766	0.444
TG (mmol/L)	1.49 ± 0.51	1.55 ± 0.41	–1.071	0.285
HDL-C (mmol/L)	0.96 ± 0.18	0.92 ± 0.21	1.815	0.070
LDL-C (mmol/L)	2.14 ± 0.58	2.19 ± 0.49	–0.895	0.372
HDL (mmol/L)	1.13 ± 0.31	1.19 ± 0.42	–1.571	0.117
LDL (mmol/L)	2.41 ± 0.68	2.42 ± 0.67	–0.151	0.880
NT-ProBNP peak value (pg/mL)	1215.77 ± 542.02	449.33 ± 222.01	15.059	<0.001
TBIL (μmol/L)	16.58 (12.13, 22.02)	13.22 (8.69, 18.20)	–4.524	<0.001
GFR (%)	133.82 ± 30.14	137.94 ± 31.53	–1.235	0.218
RDW (%)	45.48 ± 4.81	43.69 ± 3.86	3.670	<0.001
NE/LY	1.83 (1.45, 2.45)	1.88 (1.46, 2.44)	–0.031	0.975

Abbreviation: WBC, white blood cells; CRP, C-reactive protein; FIB, fibrinogen; TC, total cholesterol; TG, triglyceride; HDL-C, high density lipoprotein-cholesterol; LDL-C, low density lipoprotein-cholesterol; HDL, high density lipoprotein; LDL, low density lipoprotein; NT-ProBNP, N-terminal pro-brain natriuretic peptide; TBIL, total bilirubin; GFR, glomerular filtration rate; RDW, red cell distribution width; NE/LY, neutrophil/lymphocyte.

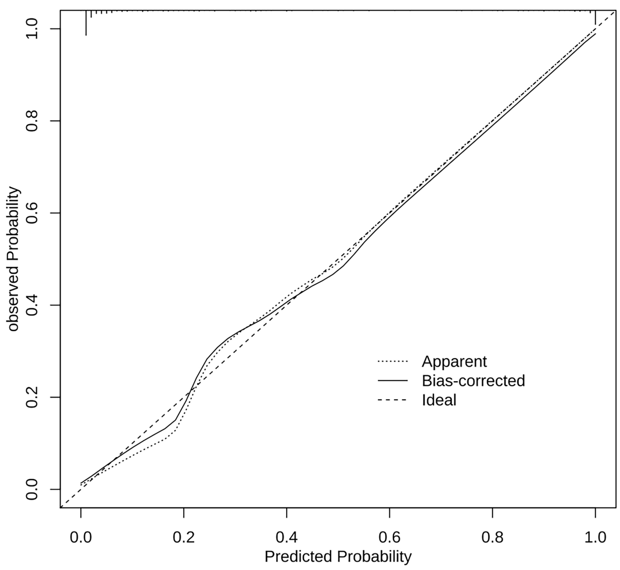

Fig. 2. Calibration figure of the Nomogram model.

ative arrhythmia in CHD patients by multi-factor (logistic regression) analysis. Our data revealed that diastolic pressure, heart function grade at III–IV, creatinine, CRP, NT-ProBNP peak value, TBIL and RDW were the risk factors for postoperative arrhythmia in CHD patients. These influencing factors largely fill the gap of prediction indicators in the postoperative arrhythmia of CHD patients.

Diastolic pressure and heart function grade at III–IV are cardiac function-related indicators. The abnormal decrease of diastolic pressure and the higher heart function grade hint the poor cardiac function in CHD patients [25–27]. The decreased diastolic pressure is associated with atrial arrest in patients with hyperkalemia [28]. A previous study showed that diastolic function grading may improve risk stratification for arrhythmic death [29]. Moreover, creatinine is a classic indicator in the urinary system, abnormal increase of which often indicates the renal dysfunction [30]. It has been documented that age, creatinine, and ejection fraction are valuable risk indexes for assessing atrial fibrillation recurrence after radiofrequency catheter ablation [31], and the uric acid: creatinine ratio is associated with recurrence of atrial fibrillation after catheter ablation [32]. CRP is a kind of inflammation-related indicator, and the higher CRP level signifies more severe inflammation response [33]. Many studies indicated CRP directly affects cardiomyocyte calcium homeostasis, aggravates arrhythmia, and may be an important risk factor for many cardiovascular diseases (coronary heart disease, dilated cardiomyopathy, atrial fibrillation) [34–36]. The high NT-ProBNP and TBIL levels often indicate the occurrence of heart failure [37] and liver injury [38], respectively. The higher RDW value suggests more diverse sizes of red blood cells in the blood, usually representing some abnormal pathological changes in the blood [39]. Moreover, when atrial fib-

Table 4. Logistic regression analysis results of risk factors of postoperative arrhythmia in CHD patients.

Indicator	b	S_b	Wald χ^2	p	OR	OR 95% CI
Diastolic pressure	–0.058	0.019	9.500	0.002	0.943	0.909–0.979
Heart function grade at III–IV	2.198	0.480	20.998	<0.001	9.010	3.518–23.070
Creatinine	0.067	0.019	12.183	<0.001	1.069	1.030–1.110
CRP	0.368	0.081	20.883	<0.001	1.445	1.234–1.692
NT-ProBNP peak value	0.006	0.001	47.911	<0.001	1.006	1.004–1.008
TBIL	0.075	0.033	5.047	0.025	1.078	1.010–1.151
RDW	0.139	0.057	5.894	0.015	1.149	1.027–1.285
Constant	–18.857	3.714	25.785	<0.001	—	—

Abbreviation: CHD, coronary heart disease; CRP, C-reactive protein; NT-ProBNP, N-terminal pro-brain natriuretic peptide; TBIL, total bilirubin; RDW, red cell distribution width; OR, odds ratio; CI, confidence interval.

rillation occurs, the production of inflammatory cytokines such as tumor necrosis factor (TNF)-α, interleukin (IL)-1 and IL-6 increase, and inflammation reduces the survival of red blood cells, leading to a decrease in the residence time of red blood cells in circulation [40]. RDW is a simple predictor of the onset and recurrence of atrial fibrillation and is associated with adverse outcomes in a variety of settings and conditions. In this research, these indicators are the risk factors of postoperative arrhythmia in CHD patients, suggesting the intimate correlation between postoperative arrhythmia and systemic diseases.

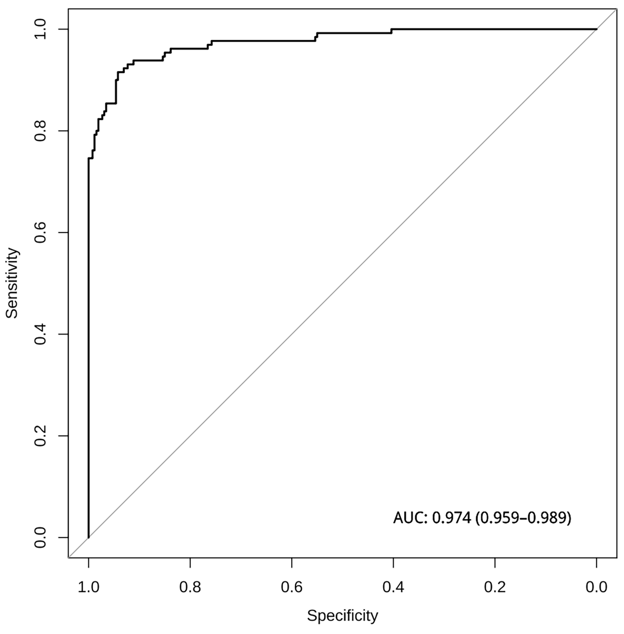

Fig. 3. ROC curve of the Nomogram model. Abbreviation: AUC, area under the curve; ROC, receiver operator characteristic.

The Nomogram is a visual expression of regression equation, which makes the prediction process of the prediction model more intuitive and convenient, and facilitates clinicians to evaluate the risk of disease in patients [41]. The established Nomogram risk model in this study has been verified to be effective in predicting the occurrence of postoperative arrhythmia in CHD patients, which has an important clinical value.

Limitations

(1) A lack of longitudinal follow-up: The study lacks follow-up data post-PCI surgery, which is crucial for understanding the long-term effectiveness and reliability of the Nomogram model in predicting postoperative arrhythmia in CHD patients.

(2) Limited sample and scope: The study is limited to a single center with a relatively small sample size, which may fail to provide a comprehensive evaluation on the model's applicability across different demographics or geographic locations.

(3) Generalizability concerns: It is unclear whether the Nomogram model is suitable for predicting arrhythmias induced by other types of cardiac surgeries beyond PCI, and alternative statistical methods or machine learning approaches could be used to refine the predictive accuracy of the model in the future.

(4) Comprehensiveness of risk factors: The study may not have captured all potential risk factors, particularly genetic markers that may play a significant role in the occurrence of postoperative arrhythmia.

Conclusion

To sum up, we found that diastolic pressure, heart function grade at III–IV, creatinine, CRP, NT-ProBNP peak value, TBIL and RDW are the risk factors of postoperative arrhythmia in CHD patients. Moreover, the Nomogram model based on these risk factors has good prediction efficiency and underlying clinical value, which is worthy of popularization and application. In future investigations, we will formulate a multi-center observation with larger sample size and scope to further verify our Nomogram model.

Availability of Data and Materials

The analyzed data sets generated during the study are available from the corresponding author on reasonable request.

Author Contributions

Substantial contributions to conception and design: JG. Data acquisition, data analysis and interpretation: ZH, XL. Drafting the article or critically revising it for important intellectual content: JG. Editorial changes in the manuscript: All authors. Final approval of the version to be published: All authors. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of the work are appropriately investigated and resolved: All authors.

Ethics Approval and Consent to Participate

Written informed consent had been signed by each patient. This research was approved by the Ethical Committee of Qingdao Municipal Hospital (Group) (the ethics approval number: 2024-LW-042) and in accordance with the declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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