BMC Cardiovascular Disorders

RESEARCH

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Risk analysis and risk prediction of in-hospital heart failure in patients with acute myocardial infarction after emergency intervention surgery

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Abstract

Background Percutaneous coronary intervention (PCI) can rapidly open the culprit vessels of acute myocardial infarction (AMI) and save ischemic myocardium, but it is often accompanied by a variety of complications, including heart failure (HF).

Objective We aimed to (i) analyze the possible risk factors affecting the occurrence of in-hospital HF after emergency PCI in patients with AMI through clinical data and (ii) establish a personalized risk prediction model for the occurrence of HF after emergency PCI in patients with AMI.

Methods Clinical data of 676 AMI patients who consecutively underwent emergency PCI between January 2020 and October 2023 at the First Affiliated Hospital of Guangxi University of Chinese Medicine were collected. Based on whether in-hospital HF occurred after PCI, the study subjects were divided into the HF group (91 cases) and the non-HF group (585 cases). Independent risk factors were screened using univariate and multivariate logistic regression. A nomogram model of the risk of HF was drawn using R, and the discriminative power was evaluated by calculating the area under the ROC curve and drawing the calibration curve and decision curve.

Results In this study, the incidence of in-hospital HF events in AMI patients after emergency PCI was 13.46%. The analysis showed that age, troponin levels, D-dimer levels, left ventricular ejection fraction (LVEF), and Gensini score were independent predictors of the occurrence of in-hospital HF in AMI patients after emergency PCI ($P<0.05$). The AUC of the nomogram model were 0.87 (95% CI: 0. 82–0.91) and 0.85 (95% CI: 0. 76–0.93) in the training and validation sets, respectively. The Hosmer–Lemeshow goodness-of-fit test in the training set suggested that the difference between predicted and actual risks of the predictive model was not statistically significant ($\chi^2=5.8185$, $P=0.6676$), and this was confirmed by the Hosmer–Lemeshow goodness-of-fit test in the validation set ($\chi^2=9.4774$, $P=0.3036$).

Conclusions The predictive model for the risk of in-hospital HF in AMI patients after emergency PCI includes age, troponin levels, D-dimer levels, LVEF, and Gensini score. It has a good differentiation ability and good accuracy, it can be used to intuitively and independently screen high-risk populations, and it has high predictive value for the occurrence

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of HF after PCI in AMI patients, so it can be used to assist clinicians in early screening, in identifying patients at high risk of postoperative HF, and in the implementation of targeted intervention therapy.

Keywords Acute myocardial infarction, Percutaneous coronary intervention, Heart failure, Prediction model, Risk factors

Strengths and limitations of this study

We objectively analyzed the risk factors for the development of HF after emergency PCI in patients with AMI, which is of practical significance.

The prediction model has a good differentiation ability and good accuracy, and it can be used to intuitively and independently screen high-risk groups with high predictive value.

This model can be used to assist clinicians in early screening, in the identification of patients at high risk of developing postoperative HF, and in the implementation of targeted intervention therapy.

The risk factors identified in this study are all commonly examined clinical parameters. Expensive and time-intensive tests are not required and the economic burden of patients is not increased, so the model is suitable for widespread dissemination.

Introduction

According to the China Cardiovascular Health and Disease Report 2022 [1], thenumber of people suffering from coronary heart disease in China is 11.39 million, and in recent years, the global mortality rate of AMI has been on the rise. AMI refers to myocardial necrosis caused by acute and persistent ischemia and hypoxia of the coronary arteries, which is a common and serious type of coronary heart disease with the characteristics of acute onset, high mortality and recurrence rates, and unsatisfactory prognosis [2]. Myocardial ischemic necrosis can cause different degrees of myocardial damage, leading to cardiac insufficiency, so AMI patients are at high risk of cardiac insufficiency. With the increase in patients with coronary artery disease and the continuous promotion and application of interventional techniques, the prevention and treatment of postinterventional complications have become a major concern in the cardiovascular field. The incidence of in-hospital HF after emergency PCI, which is closely related to mainly cardiac arrhythmia, fluid overload, and infections, has gradually risen [3]. According to Chinese and international guidelines, adequate hydration therapy is required after interventional procedures to promote contrast agent metabolism to reduce the occurrence of contrast-induced nephropathy, which undoubtedly increases the risk of postoperative acute HF. Acute HF is a critical cardiovascular condition with rapid onset, rapid progression, and poor prognosis that requires attention from clinical workers. Early screening and identification of patients at high risk of in-hospital HF after emergency PCI can help clinicians develop timely preventive strategies to improve the prognosis of this population. However, few studies have been reported on the risk factors for the occurrence of in-hospital HF after emergency PCI in patients with AMI. Therefore, in the present study, we constructed a risk prediction model based on the independent risk factors for the occurrence of in-hospital HF in patients with AMI, aiming to help clinicians in diagnostic and therapeutic decision making, to reduce the occurrence of cardiovascular and cerebrovascular events, and to reduce the physical, mental, and economic stress of patients.

Materials and methods

Research subjects

In total, 676 patients with AMI, including 513 males and 163 females, who were admitted to the Second Department of Cardiovascular Medicine of the First Affiliated Hospital of Guangxi University of Chinese Medicine for emergency PCI treatment between January 2020 and October 2023 were selected. The flow diagram of the study design is shown in Fig. 1.

Inclusion and exclusion criteria

Inclusion criteria: (1) The initial diagnosis was based on the AMI diagnostic criteria issued by the American Heart Association (ACC/AHA) [4]; (2) patients who met the criteria for PCI treatment and successfully underwent emergency PCI; (3) AMI patients with coronary stenosis undergoing PCI, with target vessel lesion diameter stenosis $>50\%$ or area stenosis $>75\%$ and tube diameter 2.5–4.0 mm; and (4) age ≥ 18 years. Exclusion criteria: (1) A preoperative history of acute or chronic HF caused by viral myocarditis, dilated cardiomyopathy, rheumatic heart disease, etc.; (2) the presence of respiratory, digestive, hematological, or immune system diseases, malignant tumors, etc.; and (3) the absence of clinical data, where missing values could not be obtained from the Hospital Information System. All patients signed written informed consent before surgery.

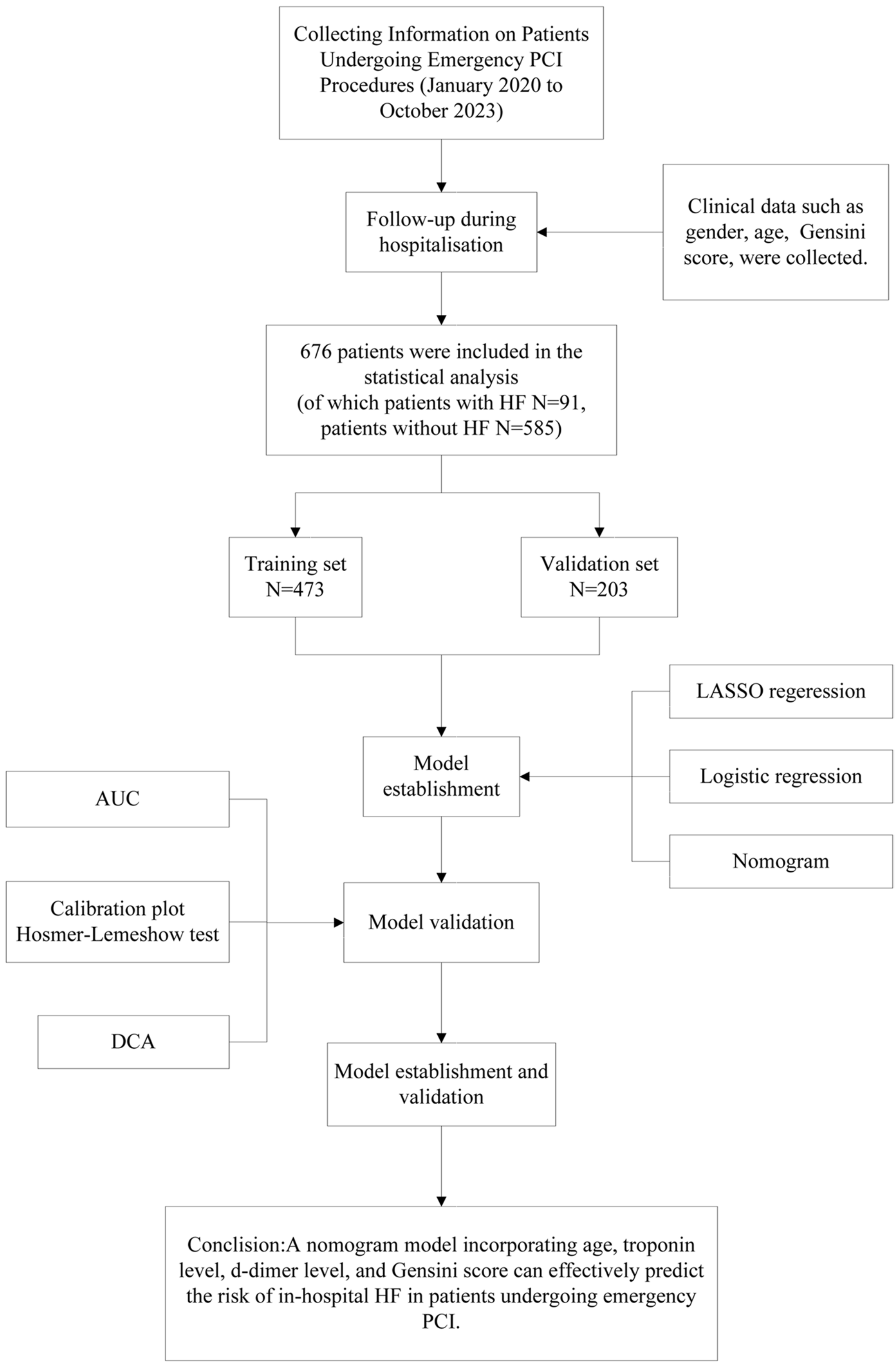

Fig. 1 Flow diagram of the study. PCI: percutaneous coronary intervention; HF: heart failure; LASSO: least absolute shrinkage and selection operator; AUC: area under curve; DCA: decision curve analysis

Data collection

This is a retrospective observational study. Patients' disease-related data, demographic data, intraoperative PCI data, and laboratory and echocardiographic examination data were collected, including gender, age, smoking status, whether they drank alcohol, Gensini score, preoperative systolic blood pressure, preoperative diastolic blood pressure, preoperative random blood glucose, the occurrence of intra-procedural complications of PCI (reperfusion arrhythmia, slow or no reflow, vasovagal reaction, coronary artery spasm, bleeding, etc.), comorbidities (hypertension, diabetes mellitus, hyperlipidemia, cerebral infarction, and chronic renal disease), troponin levels, D-dimer levels, the number of stents placed, the number of diseased branches, and echocardiographic findings on postoperative day 1 (left ventricular ejection fraction [LVEF] and left ventricular internal diastolic diameter [LVEDd]).

Diagnostic criteria

The diagnosis of HF was made according to the diagnostic criteria in the Chinese guidelines for the management of acute HF in the emergency setting (2022) [5].

Statistical analysis

Statistical analyses were performed using SPSS 25.0 and R (version 4.2.3). Normally distributed data are expressed as $x \pm s$; the independent sample *t*-test was used for comparison between groups. Non-normally distributed data are expressed as M (P25, P75); the non-parametric test was used for comparison between groups. Count data are expressed as the number of cases and the percentage; the χ^2 test was used for comparison between groups of dichotomous variables and the rank-sum test was used for comparison between groups of multicategorical variables. Random numbers were generated using R software to assign patients included in the study into training set (70%) and validation set (30%). A risk prediction model was constructed in the training set, and independent risk factors were screened by lasso regression and multivariate logistic regression, while eliminating multicollinearity in the variables. Based on the results of least absolute shrinkage and selection operator (LASSO) regression and multivariate logistic regression, a visual nomogram model was constructed using the "rms" package in R (version 4.2.3). To prevent overfitting of the model, the accuracy of the prediction model was validated in the validation set according to the internal validation method in the statement of the prediction model of TRIPOD [6], and the model's discriminative ability was examined by the area under the ROC curve (AUC) after the internal validation. The Calibration curve, the Hosmer–Lemeshow goodness-of-fit test, and the calibration curve were used to evaluate the calibration and decision curve analysis (DCA) of the model. All statistical tests were two-sided, and differences were considered statistically significant at $P < 0.05$.

Results

Comparison of baseline characteristics between the training and validation set

676 patients were randomly divided into training and validation sets of 70% and 30%, with training set $n = 473$ and validation set $n = 203$ (Table 1). The training set included 58 patients with HF, or 12.2% of this group; the validation set included 33 patients with HF, or 16.2% of this group. Statistical analysis of the general data showed that the difference was not significant ($P > 0.05$), as shown in Table 1. This indicates that the indicators in the training and validation sets are evenly distributed, which can effectively avoid conclusion bias.

Univariate analysis of the risk of in-hospital HF after emergency PCI in patients with AMI

The univariate analysis results showed that the difference in the distribution of seven variables, namely, age, preoperative diastolic blood pressure, troponin levels, D-dimer levels, LVEF, LVEDd, combined hypertension, combined Chronic renal disease, and Gensini score, between patients in the HF group and those in the non-HF group was statistically significant (all $P < 0.05$), as shown in Table 2.

Screening for predictive factors by LASSO and multivariate logistic regression

We screened these predictors by LASSO regression, which may eliminate multicollinearity in the variables. This model uses a tenfold cross-validation LASSO regularization algorithm to explore the optimal parameters, as shown in Fig. 2. Five variables with nonzero regression coefficients were finally output at lambda.min. These five variables included age, troponin level, d-dimer level, LVEF, and Gensini scores. Then multivariate logistic regression analysis. With the occurrence of HF as the dependent variable (assigned value: occurrence = 1, no occurrence = 0), the above 5 variables with statistically significant differences were included in the logistic regression model for multiple regression analysis. Age, troponin level, d-dimer level, and Gensini score were all continuous variables, and variables were selected using a stepwise forward method (inclusion criteria: $\alpha = 0.05$). The results showed that age, troponin level, d-dimer level, and Gensini score independent risk factors for inpatient HF patients ($P < 0.05$), and LVEF were an independent protective factor for in-hospital HF after emergency PCI in AMI patients ($P < 0.05$), as shown in Table 3.

Predictive modeling of HF occurrence risk nomogram

Based on the multivariate logistic regression analysis, five risk factors, namely, age, troponin levels, D-dimer levels, LVEF, and Gensini score, were selected in this study

Table 1 Balance test for training and validation sets (M (P25, P75), cases (%))

Variables	Total ($n=676$)	train ($n=473$)	test ($n=203$)	χ2/Z	*P*
Gender (%)				0.94	0.332
Female	163 (24.11)	119 (25.16)	44 (21.67)		
Male	513 (75.89)	354 (74.84)	159 (78.33)		
Age (years)	63.00 (56.00, 71.00)	63.00 (55.00, 72.00)	62.00 (56.00, 69.00)	−0.01	0.992
SBP (mmHg)	138.00 (124.00, 151.00)	139.00 (126.00, 152.00)	138.00 (122.00, 150.00)	−1.55	0.122
DBP (mmHg)	86.00 (74.00, 93.00)	86.00 (74.00, 93.00)	85.00 (73.50, 93.00)	−0.37	0.708
RBG (mM)	6.64 (5.50, 8.10)	6.65 (5.50, 8.31)	6.60 (5.25, 7.70)	−0.93	0.350
Troponin (ng/mL)	1.23 (0.29, 3.87)	1.23 (0.29, 4.15)	1.23 (0.30, 3.35)	−0.33	0.745
D-dimer (ng/mL)	0.35 (0.17, 0.49)	0.35 (0.17, 0.50)	0.35 (0.15, 0.45)	−1.02	0.307
LVEF (%)	64.00 (59.00, 68.00)	64.00 (59.00, 68.00)	63.00 (57.00, 68.00)	−0.70	0.483
LVEDd (mm)	49.00 (45.00, 51.00)	48.00 (45.00, 51.00)	49.00 (45.00, 51.50)	−1.25	0.210
Gensini score (point)	65.00 (42.00, 91.00)	68.00 (44.00, 95.50)	63.00 (41.00, 90.00)	−1.30	0.195
Hypertension (%)				3.18	0.075
No	236 (34.91)	155 (32.77)	81 (39.90)		
Yes	440 (65.09)	318 (67.23)	122 (60.10)		
Diabetes (%)				1.31	0.252
No	464 (68.64)	331 (69.98)	133 (65.52)		
Yes	212 (31.36)	142 (30.02)	70 (34.48)		
Chronic renal disease (%)				0.22	0.639
No	589 (87.13)	414 (87.53)	175 (86.21)		
Yes	87 (12.87)	59 (12.47)	28 (13.79)		
Cerebral infarction (%)				1.22	0.270
No	535 (79.14)	369 (78.01)	166 (81.77)		
Yes	141 (20.86)	104 (21.99)	37 (18.23)		
Hyperlipidemia (%)				0.01	0.943
No	152 (22.49)	106 (22.41)	46 (22.66)		
Yes	524 (77.51)	367 (77.59)	157 (77.34)		
Smoking (%)				0.07	0.787
No	355 (52.51)	250 (52.85)	105 (51.72)		
Yes	321 (47.49)	223 (47.15)	98 (48.28)		
Drinking (%)				0.10	0.749
No	467 (69.08)	325 (68.71)	142 (69.95)		
Yes	209 (30.92)	148 (31.29)	61 (30.05)		
Complications(%)				1.019	0.313
No	607 (89.79)	425 (89.85)	182 (89.66)		
Yes	69 (10.21)	48 (10.15)	21 (10.34)		
Number of diseased branches (%)				1.42	0.491
One	144 (21.30)	105 (22.20)	39 (19.21)		
Two	241 (35.65)	171 (36.15)	70 (34.48)		
Three	291 (43.05)	197 (41.65)	94 (46.31)		
Number of stents placed (%)				-	0.955
One	405 (59.91)	282 (59.62)	123 (60.59)		
Two	265 (39.20)	187 (39.53)	78 (38.42)		
Three	6 (0.89)	4 (0.85)	2 (0.99)		

SBP Systolic blood pressure, *DBP* Diastolic blood pressure, *RBG* Random blood glucose, *LVEF* Left ventricular ejection fraction, *LVEDd* Left ventricular internal diastolic diameter

Table 2 Univariate analysis of the risk of developing HF after emergency PCI in 473 patients with AMI in the training set (M (P25, P75), cases (%))

Variables	Total (*n* = 473)	Non-HF (*n* = 415)	HF (*n* = 58)	χ^2/Z	*P*
Gender (%)				0.70	0.402
Female	119 (25.16)	107 (25.78)	12 (20.69)		
Male	354 (74.84)	308 (74.22)	46 (79.31)		
Age (years)	63.00 (55.00, 72.00)	62.00 (54.00, 71.00)	67.00 (62.00, 77.00)	−3.84	<.001
SBP (mmHg)	139.00 (126.00, 152.00)	140.00 (126.00, 152.00)	132.50 (123.50, 149.00)	−1.85	0.064
DBP (mmHg)	86.00 (74.00, 93.00)	86.00 (75.00, 93.00)	78.00 (70.00, 92.75)	−1.86	0.063
RBG (mM)	6.65 (5.50, 8.31)	6.60 (5.50, 7.94)	6.95 (5.82, 9.18)	−1.81	0.071
Troponin (ng/mL)	1.23 (0.29, 4.15)	1.03 (0.24, 3.45)	3.29 (0.71, 9.85)	−3.90	<.001
D-dimer (ng/mL)	0.35 (0.17, 0.50)	0.31 (0.15, 0.47)	0.59 (0.34, 1.64)	−5.80	<.001
LVEF (%)	64.00 (59.00, 68.00)	65.00 (60.00, 69.00)	54.50 (45.00, 63.00)	−6.32	<.001
LVEDd (mm)	48.00 (45.00, 51.00)	48.00 (45.00, 51.00)	50.00 (45.25, 53.00)	−2.34	0.019
Gensini score (point)	63.00 (41.00, 90.00)	60.00 (40.00, 86.00)	85.00 (70.50, 107.50)	−5.01	<.001
Hypertension (%)				1.43	0.231
No	155 (32.77)	140 (33.73)	15 (25.86)		
Yes	318 (67.23)	275 (66.27)	43 (74.14)		
Diabetes (%)				0.02	0.900
No	331 (69.98)	290 (69.88)	41 (70.69)		
Yes	142 (30.02)	125 (30.12)	17 (29.31)		
Chronic renal disease (%)				5.98	0.014
No	414 (87.53)	369 (88.92)	45 (77.59)		
Yes	59 (12.47)	46 (11.08)	13 (22.41)		
Cerebral infarction (%)				1.21	0.272
No	369 (78.01)	327 (78.80)	42 (72.41)		
Yes	104 (21.99)	88 (21.20)	16 (27.59)		
Hyperlipidemia (%)				0.00	0.999
No	106 (22.41)	93 (22.41)	13 (22.41)		
Yes	367 (77.59)	322 (77.59)	45 (77.59)		
Smoking (%)				1.49	0.222
No	250 (52.85)	215 (51.81)	35 (60.34)		
Yes	223 (47.15)	200 (48.19)	23 (39.66)		
Drinking (%)				0.00	0.964
No	325 (68.71)	285 (68.67)	40 (68.97)		
Yes	148 (31.29)	130 (31.33)	18 (31.03)		
Complications(%)				2.09	0.148
No	425 (89.85)	376 (90.60)	49 (84.48)		
Yes	48 (10.15)	39 (9.40)	9 (15.52)		
Number of diseased branches (%)				2.36	0.307
One	105 (22.20)	88 (21.20)	17 (29.31)		
Two	171 (36.15)	154 (37.11)	17 (29.31)		
Three	197 (41.65)	173 (41.69)	24 (41.38)		
Number of stents placed (%)				-	0.121
One	282 (59.62)	248 (59.76)	34 (58.62)		
Two	187 (39.53)	165 (39.76)	22 (37.93)		
Three	4 (0.85)	2 (0.48)	2 (3.45)		

to establish a prediction model for in-hospital HF after emergency PCI in AMI patients. A visual nomogram model was successfully constructed using R (see Fig. 3), which assigns different scores to each clinical indicator and can predict the risk of in-hospital HF after emergency PCI in patients with AMI based on the total score.

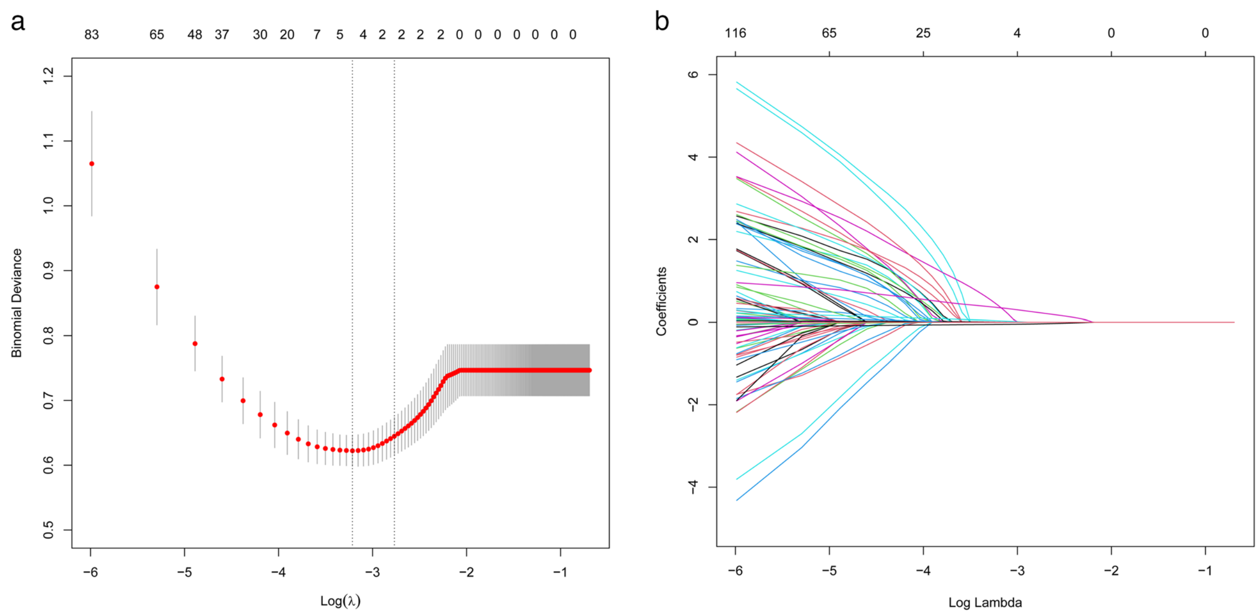

Fig. 2 LASSO regression diagram

Table 3 Multivariate logistic regression analysis of the risk of in-hospital HF after emergency PCI

Variable	B	SE	Z	P	OR	2.5%	97.5%
Constant	−1.741	1.510	−1.153	0.249	0.175	0.009	3.380
Age (years)	0.033	0.015	2.147	0.032	1.034	1.003	1.066
Troponin (ng/mL)	0.137	0.047	2.925	0.003	1.147	1.046	1.258
D-dimer (ng/mL)	0.702	0.190	3.695	< .001	2.018	1.390	2.928
LVEF (%)	−0.079	0.017	−4.763	< .001	0.924	0.894	0.955
Gensini score (point)	0.017	0.005	3.755	< .001	1.018	1.008	1.027

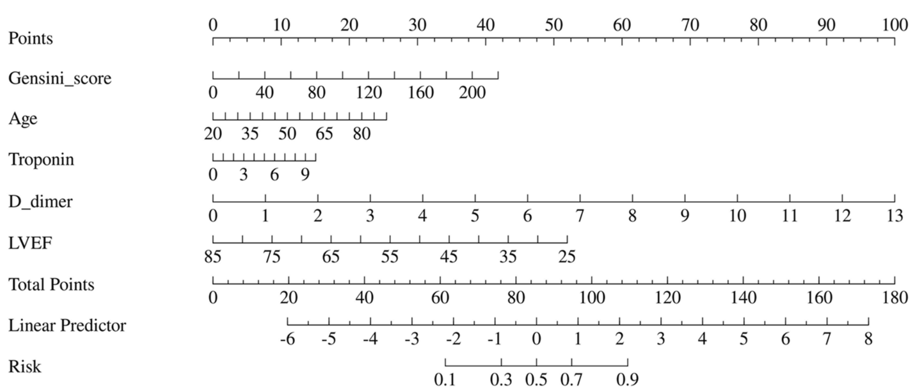

Fig. 3 Nomogram of HF occurring after emergency PCI in patients with AMI

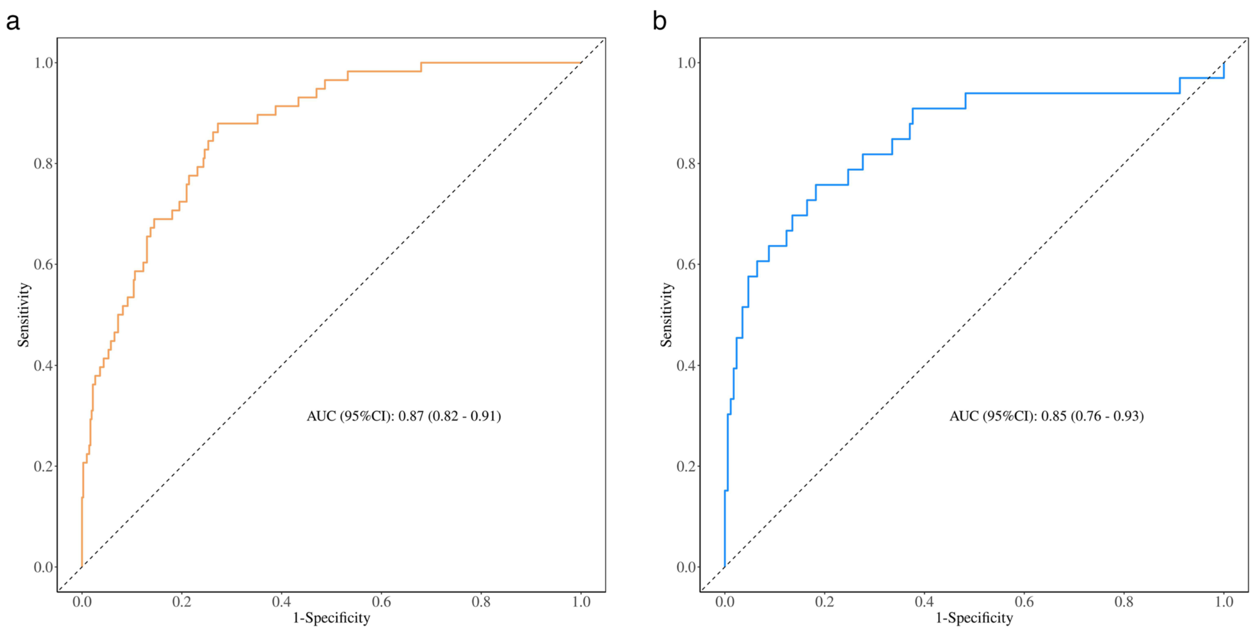

Fig. 4 ROC curve for the occurrence of HF after emergency PCI in AMI patients in the training and validation sets. **a**: ROC curve in the training set; **b**: ROC curve in the validation set

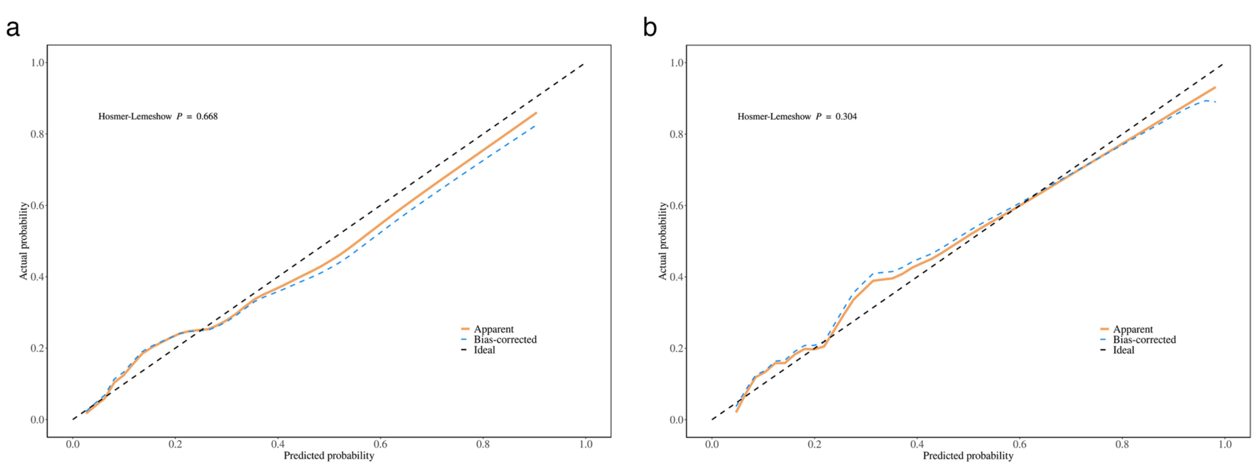

Fig. 5 Calibration curve for the occurrence of HF after emergency PCI in AMI patients in the training and validation sets. **a**: Calibration curve in the training set; **b**: Calibration curve in the validation set

Based on the total score, the risk of in-hospital HF after PCI could be predicted in patients with AMI. The higher the total score, the higher the risk of in-hospital HF.

Evaluation and internal validation of the model

The AUC of the model in the training set was 0.87 (95% CI: 0. 82–0. 91), and the AUC of the model in the validation set was 0.85 (95% CI: 0. 76–0. 93), which proved that the model had good discriminatory ability (see Fig. 4); the calibration curve confirmed the good agreement between the predicted risk and the actual risk (see Fig. 5). The Hosmer–Lemeshow goodness-of-fit test in the training set suggested that the difference between predicted and actual risks of the model was not statistically significant ($\chi^2=5.8185$, $P=0.6676$), and this was confirmed by the Hosmer–Lemeshow goodness-of-fit test in the validation set ($\chi^2=9.4774$, $P=0.3036$).

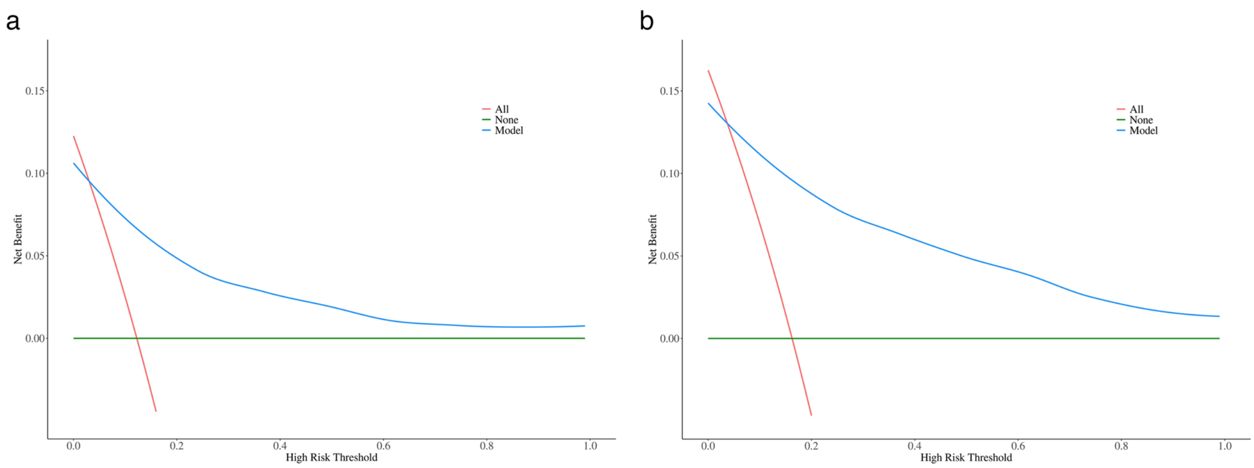

Fig. 6 Decision curve for the occurrence of HF after emergency PCI in AMI patients in the training and validation sets. **a**: Decision curve in the training set; **b**: Decision curve in the validation set

DCA

DCA shows the clinical usefulness of the model, with the horizontal line indicating the net benefits in the treatment strategies of patients without HF and the diagonal line indicating the net benefits in the treatment strategies of all patients with HF. The wide range of high-risk threshold probabilities from DCA suggests that the model has clinical application value (see Fig. 6).

Discussion

Acute HF is one of the major adverse cardiovascular event events after emergency PCI and in this study in its incidence was 13.46% (91/676) which is similar to previous studies (10%–45%) [7]. HF can lead to further deterioration of the patient's condition and eventually death, requiring rapid diagnostic evaluation and emergency treatment. Therefore, in the present study, we constructed a model to predict the occurrence of HF after surgery, aiming to support clinicians in diagnostic and therapeutic decision making, reduce the occurrence of cardiovascular and cerebrovascular adverse events, and reduce the physical, mental, and economic pressure of patients. The results of the study showed that age, troponin levels, D-dimer levels, LVEF, and Gensini score, which are the five independent factors influencing the occurrence of HF in post-PCI patients screened in this study, have been confirmed to have a close relationship with the occurrence and development of HF in other studies.

Age is an independent risk factor for patients with HF, and elderly patients tend to have more underlying-disease, which further reduces cardiac perfusion during myocardial infarction, exacerbating the risk of developing HF and rapid progression of the disease [8]. Studies have shown that advanced age is associated with a higher risk of HF, cardiogenic shock, in-hospital cardiac arrest, stroke, reinfarction, and composite endpoint events in STEMI patients undergoing PCI [9]. Therefore, we should pay more attention to elderly AMI patients, perform intraoperative and postoperative observation and follow-up, and find abnormalities in a timely manner to provide targeted interventions and guidance to reduce the risk of HF.

The level of troponin, an indicator of the severity of cardiomyocyte injury, is not affected by the demographic characteristics of the patient and is widely used not only in the diagnosis of cardiovascular diseases but also in postoperative evaluation. When cardiomyocytes are functionally injured, cTnI from the cytoplasm rapidly enters the bloodstream, resulting in elevated serum cTnI levels. A higher troponin level indicates more severe cardiomyocyte injury and a higher risk of acute insufficiency. Meanwhile, when AMI patients are complicated by HF, the heart will increase the level of myocardial fibrosis under the influence of neurofluid and mechanical stimuli and reduce synchrony and cardiac contractility to further aggravate cardiomyocyte damage, so that a large amount of troponin is released into the blood circulation [10]. One study also confirmed that the troponin level is an independent risk factor for HF [11], which can be used in the assessment of cardiac remodeling and serve as a reference for clinical follow-up.

The D-dimer level is a valuable marker of coagulation and fibrinolytic activation and is often used to assess coagulation function. It has been shown that healthy individuals have low D-dimer levels in their circulation and that patients in thrombosis-related conditions have high D-dimer levels. Previous studies have shown that

HF is associated with a prethrombotic state and disturbances in the coagulation system [12]. Elevated D-dimer levels can be used to predict not only the incidence of major adverse cardiovascular events in patients with non-ST-segment elevation myocardial infarction [13, 14] but also the onset of HF, as well as adverse outcomes in patients with HF [15].

LVEF, as the preferred auxiliary diagnostic index for cardiac function assessment, is a dynamic indicator that is closely related to cardiac function, hemodynamic instability, and the risk of adverse outcomes. Myocardial necrosis and insufficient cardiac systolic ejection function in patients with AMI result in a decrease in the LVEF, which can easily lead to the development of HF. Echocardiography not only is a powerful tool for predicting and directly observing cardiac insufficiency but also suggests the risk of a variety of adverse cardiovascular events in patients after PCI for coronary artery disease [16, 17].

The Gensini score is a method used to assess the extent of coronary artery lesions, which scores the lesions according to the extent and extent of coronary artery stenosis [18, 19]. The Gensini score is positively associated with the occurrence of MI associated with PCI, and a high Gensini score usually reflects severe coronary lesions [20], which can lead to insufficient blood supply or myocardial infarction, thus increasing the risk of HF. Therefore, patients with a high Gensini score are more likely to develop HF after MI [21]. This suggests that the Gensini score can be used as an indicator to predict the risk of HF, especially in assessing the risk of HF after MI, which can help physicians evaluate the patient's condition, guide the development of treatment plans and the evaluation of prognosis.

Risk prediction modeling research aims to estimate the probability of an event occurring in an individual [6], and the present model is built on multifactor regression analysis, integrating multiple predictor variables to personalize and accurately predict the probability of an event occurring. The AUC values for both the training and validation sets indicate that the present model exhibits excellent differentiation, calibration, and scientific validity [22]. In addition, its clinical translation is relatively simple, as the risk probability of HF occurrence can be derived directly from the model based on the assigned scores for each variable. Healthcare professionals can utilize the paper version of the nomogram model or convert it to a dynamic nomogram set up in a microsoft app and make a web-based calculator for use. Making it easy to visualize and intuitive to use [23].

Emergency PCI is currently one of the most effective means of treating AMI. In recent years, society has experienced remarkable progress, but due to the influence of poor living habits, the incidence of coronary heart disease is increasing year by year, while the average age of people with coronary heart disease is decreasing. The number of patients with AMI who receive emergency PCI treatment is also increasing, and the incidence of postoperative cardiovascular adverse events is increasing as well. HF can lead to further deterioration of the patient's condition and eventually death, affecting public health globally [24]. The prevention and treatment of AMI remains challenging and has become a disease of major concern. The use of appropriate measurement tools to assess the risk of HF in patients with AMI can help to develop targeted interventions to minimize the occurrence of HF, which is important for improving the quality of life of patients and reducing the burden of care. Therefore, the development of high-quality risk prediction tools has become the focus of research on the prevention and treatment of adverse cardiovascular events in AMI patients. In recent years, scholars in various countries have constructed various risk prediction models for the development of coronary heart disease based on local population characteristics and epidemiologic data.

Currently, studies in China have confirmed that risk prediction model is useful in predicting the risk of ischemia–reperfusion injury after PCI [25], the risk of cardiac arrest during hospitalization in patients with acute coronary syndromes [26], the risk of in-hospital death [27], the risk of in-hospital hemorrhage in patients with acute ST-segment elevation myocardial infarction [28], the risk of concurrent acute renal injury [29], the risk of HF in patients with acute coronary syndromes, and the risk of HF in patients with acute ST-segment elevation myocardial infarction [30]. In coronary syndrome patients, PCI has good therapeutic effects in terms of the risk of hemodilution reconstruction 6 months after PCI [30]. However, a variety of risk prediction models have been constructed, and the predictors incorporated in each model are inconsistent, and the content of the assessment and the applicable population are not uniform, resulting in a certain gap between the prediction results and the actual situation. Meanwhile, few studies have been reported on the histogram of the risk of in-hospital HF after emergency PCI in AMI patients. Therefore, in this study, we constructed a model to predict the occurrence of postoperative HF. Based on this model, the risk of in-hospital HF after emergency PCI in patients with AMI can be predicted effectively and conveniently. The model can help clinical staff to identify patients at high risk of HF in a timely and early manner, thus providing early intervention to minimize the harmful effects of HF on people's lives and health.

However this study also contains the following limitations. (1) This study is a single-center retrospective observational study, and despite internal validation, this may lead to a certain bias, and therefore, it is still necessary to expand the sample size or carry out a multicenter study to further assess the clinical predictive value of the model. (2) We only carried out internal validation of the constructed model, impeding extrapolation of the model. It is necessary to collaborate with other clinical research centers to externally validate the predictive effect of this model. (3) The indicators included in this study and the predictive indicators in the prediction model are limited; the data of some risk factors could not be obtained, so the predictive efficacy of the prediction model needs to be further improved. It is expected that the inclusion of more predictive risk indicators in future studies will have great practical significance by improving the predictive effect of the model.

Acknowledgements
We thank LetPub (www.letpub.com) for its linguistic assistance during the preparation of this manuscript.

Authors' contributions
Hui Song, Wei-bin Qin and Wei-zhi Tang wrote the main manuscript text and Fei-fei Yang prepared figs. 1, 2, 3, 4, 5, 6. All authors reviewed the manuscript.

Funding
This study was supported by the NATCM's Project of High-level Construction of Key TCM Disciplines (zyyzdxk-2023166), the Guangxi Science and Technology Key R&D Program Project (Project No. Gui Ke AB19110006) and the Guangxi Science and Technology Key Project (Project No. 2020GZNSFDA297020).

Data availability
The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethics approval was obtained from the independent ethical review board of the First Affiliated Hospital of Guangxi University of Chinese Medicine (approval number: 2022–095-02). The study was performed in accordance with the Declaration of Helsinki.

Consent for publication
All participants gave written informed consent to participate in the study.

Competing interests
The authors declare no competing interests.

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Received: 7 January 2024 Accepted: 18 November 2024
Published online: 25 November 2024

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