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Nomogram for Predicting in-Hospital Severe Complications in Patients with Acute Myocardial Infarction Admitted in Emergency Department

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Background: There is lack of predictive models for the risk of severe complications during hospitalization in patients with acute myocardial infarction (AMI). In this study, we aimed to create a nomogram to forecast the likelihood of in-hospital severe complications in AMI.

Methods: From August 2020 to January 2023, 1024 patients with AMI including the modeling group (n=717) and the validation group (n=307) admitted in Changsha Central Hospital's emergency department. Conduct logistic regression analysis, both univariate and multivariate, on the pertinent patient data from the modeling cohort at admission, identify independent risk factors, create a nomogram to forecast the likelihood of severe complications in patients with AMI, and assess the accuracy of the graph's predictions in the validation cohort.

Results: Age, heart rate, mean arterial pressure, diabetes, hypertension, triglycerides and white blood cells were seven independent risk factors for serious complications in AMI patients. Based on these seven variables, the nomogram model was constructed. The nomogram has high predictive accuracy (AUC=0.793 for the modeling group and AUC=0.732 for the validation group). The calibration curve demonstrates strong consistency between the anticipated and observed values of the nomogram in the modeling and validation cohorts. Moreover, the DCA curve results show that the model has a wide threshold range (0.01–0.73) and has good practicality in clinical practice.

Conclusion: This study developed and validated an intuitive nomogram to assist clinicians in evaluating the probability of severe complications in AMI patients using readily available clinical data and laboratory parameters.

Keywords: acute myocardial infarction, severe complications, risk factors, nomogram

Introduction

Acute myocardial infarction (AMI) is a severe form of coronary atherosclerotic heart disease, known for its rapid onset, progression, high incidence, and mortality rates.[1,2] AMI is now the world's greatest cause of death due to its continually rising mortality rate over the last ten years[3,4]. In China, the mortality rate of AMI was reported to be between 42.23% and 62.72% from 2002 to 2016.[5] The growing population, aging demographics, and rise in long-term survivors after AMI have led to significant medical and economic burdens worldwide.[1] To address this, early risk prediction tools for severe complications in AMI patients are essential.

By utilizing cardiovascular patient data and objective risk assessment, clinicians can identify potential risks and intervene promptly to mitigate complications and reduce mortality. So far, some studies have found that some single indicators including E/e 'Ratio and Triglyceride glucose index[6,7] could be for predicting the occurrence of complications and clinical outcomes in AMI.

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Nomogram, a statistical models based on clinical and biological variables, are valuable tools for predicting complications, prognosis, and survival in various diseases, aiding in the development of personalized treatment plans. However, there is a lack of research utilizing nomogram to predict severe complications in AMI patients during hospitalization. The objective of this research is to examine the clinical features and laboratory markers of individuals with AMI in order to forecast the probability of severe complications.

Methods

Patients

From August 2020 to January 2023, all 1045 AMI patients admitted in the emergency department of Changsha Central Hospital were selected as the subjects of this study.

Definition

The global diagnostic standards for AMI encompass raised levels of myocardial markers in the serum (particularly troponin) surpassing the 99th percentile upper reference limit, together with one or more of the subsequent clinical signs: symptoms of ischemia, fresh ischemic ECG alterations (like recent ST-T adjustments or left bundle branch block), the appearance of pathological Q waves in the ECG, findings from imaging examinations revealing recent myocardial activity loss or recently formed regional wall motion irregularities, and verification of coronary artery thrombosis via coronary angiography or post-mortem examination.[8]

Severe complications of AMI include acute circulatory dysfunction, severe arrhythmia, heart failure, and death.[9]

Inclusion and Exclusion Criteria

Criteria for Inclusion: Patients Admitted in Emergency Department Diagnosed with AMI

Criteria for exclusion: Patients with AMI who expired due to concurrent aortic dissection (n=1), pulmonary embolism (n=1), stroke (n=3), inadequate data (n=16), or age< 18-year-old (n=0). A total of 21 individuals were ineligible (Figure 1).

Data Collection

The collected data includes clinical characteristics and laboratory test results of patients upon admission. The collected clinical data of patients include: general information of patients: gender, age, heart rate(HR), respiratory rate(RR), mean arterial pressure (MAP), percutaneous coronary intervention(PCI), diabetes, hypertension; laboratory indicators: triglyceride(TG), cholesterol, high-density lipoprotein(HDL), low-density lipoprotein(LDL), chlorine, ionized calcium, kalium, sodium, glucose, activated partial thromboplastin time(APTT), fibrinogen, prothrombin time(PT), international normalized ratio(INR), thrombin time(TT), urea nitrogen, creatinine, uric acid(UA), albumin, alanine aminotransferase (ALT), globulin, total bilirubin, white blood cell (WBC), lymphocyte, hematocrit, platelet (PLT), and the severe complications of AMI include death, heart failure (HF), ventricular fibrillation (VF), cardiogenic shock (CS), ventricular tachycardia (VT) and atrioventricular block (AVB).

Statistical Analysis

The statistical findings were displayed as median values (P25~P75) with group comparisons conducted through the Mann Whitney *U*-test. Count data was represented as examples (%) and between-group analyses were carried out using the chi-square test. Statistical significance was denoted by $P<0.05$. An initial database split randomly into modeling and validation subgroups at a 7:3 ratio. Within the modeling subgroup, single-factor logistic regression was applied to identify significant independent variables ($P<0.05$), which were later included in a multifactor binary logistic regression model. The validation subgroup was utilized for model validation purposes. Model performance was assessed through the area under curve (AUC) of the receiver operating characteristic, calibration curve, and decision curve analysis (DCA). The area under the ROC curve, AUC, is used to evaluate the model performance. AUC>0.7 indicates that the model performance is good.[10]

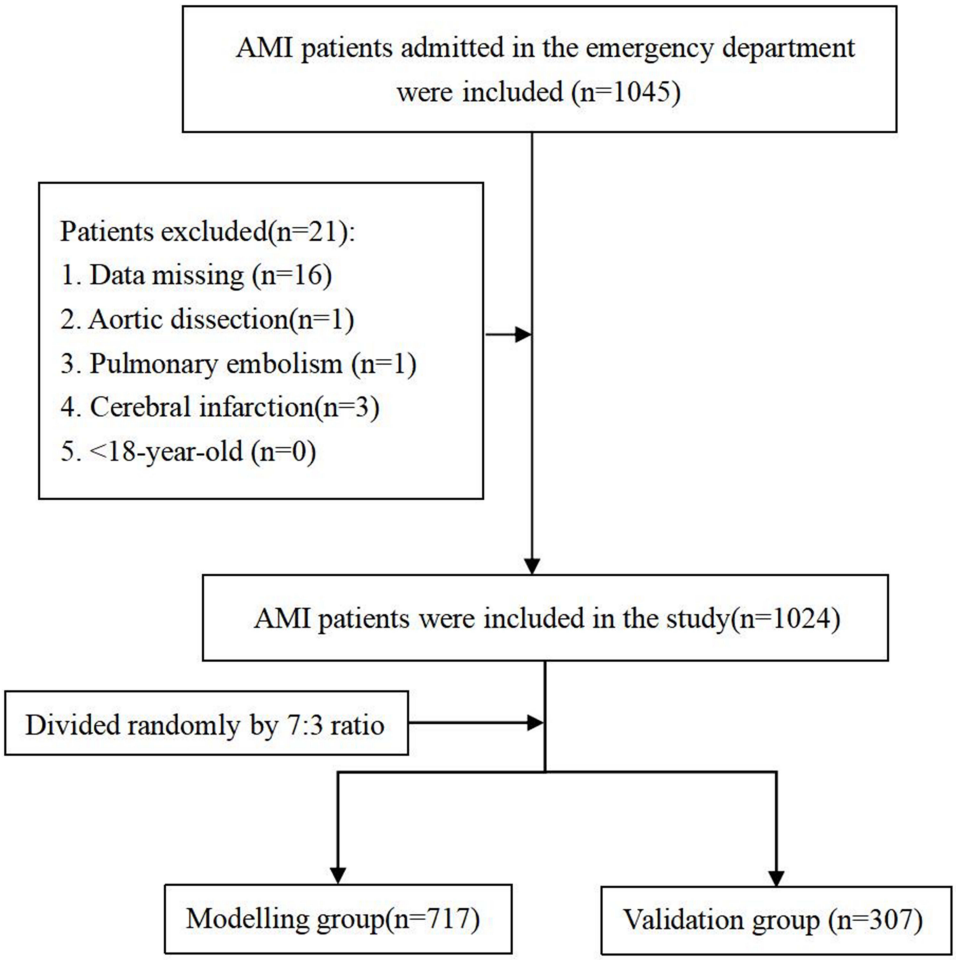

Figure 1 Flowchart.
Abbreviation: AMI, acute myocardial infarction.

Internal Validation is Evaluated Using Bootstrap Validation

The logistic regression model was utilized to create a column chart, in which every coefficient from the regression was scaled to a 0–100 point system. To forecast the likelihood of severe complications, the cumulative score was determined by adding up the scores of the individual variables. Calibration curves were employed to assess the correlation between the column charts and observed probabilities. Statistical analysis was conducted with SPSS software (version 25) and R software (42.2). A significance level of $p < 0.05$ was established for statistical significance.

Result

General Characteristics of All Patients

Based on the criteria for inclusion and exclusion, a grand total of 1024 patients with AMI were chosen, including 268 cases (26.17%) in the AMI group with severe complications and 756 cases (73.83%) in the AMI group without severe complications (Table 1). In the severe complication group (n=268) of AMI, the proportions of death, HF, VF, CS, VT and AVB accounted for 16.42% (n=44), 82.46% (n=221), 5.97% (n=16), 22.76% (n=61), 7.84% (n=21) and 5.97% (n=26), respectively. In patients with AMI, there were no notable variances observed in HDL, chlorine, sodium, APTT, globulin, total bilirubin and PLT levels between the two groups (all P>0.05). The age, WBC, lymphocyte, procalcitonin, HR, kalium, glucose, fibrinogen, PT, urea nitrogen, creatinine, UA, ALT, the proportion of female patients, diabetes and hypertension in patients without severe complications were lower than those in patients with severe complications (all P<0.05). The variables including MAP, ionized calcium, TT, albumin, and

Table 1 Comparison of Baseline Data Between AMI Group with Severe Complications and AMI Group Without Severe Complications

Variables		Non-severe Complications (n=756)			Severe Complications (n=268)			P-value
		median	P25	P75	median	P25	P75	
Demographics								
Gender (%)	Female	157	20.77%		Female	80	29.85%	0.002
	Male	599	79.23%		Male	188	70.15%	
Age(years)		63	54	72	71	60	80	<0.001
Vital signs								
HR (beats/min)		78	67	90	89	74	104.75	<0.001
RR (beats/min)		20	18	20.75	20	18	23.75	<0.001
MAP (mmHg)		102.67	89.33	116	95.17	80	109.33	<0.001
Intervention factor								
PCI (%)	No	167	22.10%		No	81	30.20%	0.008
	Yes	589	77.90%		Yes	187	69.80%	
Risk factor								
Diabetes (%)	No	581	76.85%		No	156	58.21%	<0.001
	Yes	175	23.15%		Yes	112	41.79%	
Hypertension (%)	No	410	54.23%		No	99	36.94%	<0.001
	Yes	346	45.77%		Yes	169	63.06%	
Laboratory findings								
Cholesterol (mmol/L)		4.47	3.87	5.01	4.47	3.87	5.01	<0.001
HDL (mmol/L)		0.95	0.86	1.06	0.95	0.86	1.06	0.589
LDL (mmol/L)		3.05	2.52	3.54	3.05	2.52	3.54	<0.001
TG (mmol/L)		1.75	1.27	2.44	1.75	1.27	2.44	<0.001
Chlorine (mmol/L)		104	102	107	104.06	102	107	0.844
Ionized Calcium (mmol/L)		1.19	1.14	1.23	1.16	1.11	1.21	<0.001
Kalium (mmol/L)		3.81	3.60	4.10	4	3.70	4.34	<0.001
Sodium (mmol/L)		140	139	142	139	140.86	143	0.351
Glucose (mmol/L)		7.50	6.21	9.80	8.70	6.80	12.38	<0.001
APTT(s)		25.40	23.70	27	25.35	23.43	27.80	0.726
Fibrinogen (g/L)		3	2.60	3.70	3.40	2.70	4.40	<0.001
PT(s)		10.50	10.1	11.10	11	10.40	11.90	<0.001
INR		1	1	1.08	1	1	1.10	<0.001
TT(s)		18	17	19	17	16	18.05	0.031
Urea Nitrogen (mmol/L)		5.24	4.24	6.52	6.53	4.90	8.62	<0.001
Creatinine (umol/L)		73.28	62	89	88	68	124	<0.001
UA (umol/L)		338	282.56	402.75	370.50	296	460.75	<0.001
Albumin (g/L)		42	38.41	44	39	35	42	<0.001
ALT (u/L)		26	17	38.13	28	17	52.75	0.021
Globulin (g/L)		27.36	25	30	28	24.09	31	0.602
Total Bilirubin (mmol/L)		8.90	6.4	12.34	9.40	6.60	14.08	0.104
WBC (*10^9/L)		9.40	7.68	11.52	10.48	8.52	13.47	<0.001
Hematocrit (%)		0.44	0.40	0.47	0.42	0.37	0.45	<0.001
Lymphocyte (*10^9/L)		1.81	1.23	2.60	1.54	0.96	2.60	0.004
PLT (*10^9/L)		217	184	259.75	220	182	261	0.907

Abbreviations: HR, heart rate, respiratory rate, MAP, mean artery pressure; PCI, percutaneous coronary intervention; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglyceride; APTT, activated partial thromboplastin time; PT, prothrombin time; INR, international normalized ratio; TT, thrombin time; UA, uric acid; ALT, alanine aminotransferase; WBC, white blood cell; PLT, platelet.

male proportion were all higher in the group with severe complications (all P<0.05). In the group without severe complications, a higher proportion of patients received PCI treatment compared to those in the group with severe complications (all P<0.05). (Table 1).

Baseline Data Comparison Between Modeling and Validation Groups

Table 2 displayed the baseline characteristics for the modeling group (n=717) and the validation group (n=307). With the exception of glucose and PLT levels (both P<0.05), all other laboratory indicators showed no significant differences (all P>0.05) between the two groups, meeting the criteria for random assignment.

Table 2 Comparison of Baseline Data Between Modeling Group and Validation Group

Variables	Modeling Group (n=717)			Validation Group (n=307)			P-value
	Median	P25	P75	Median	P25	P75	
Demographics							
Gender (%)	Female	171	23.85%	Female	66	21.50%	0.414
	Male	546	76.15%	Male	241	78.50%	
Age (years)	66	55	74	66	55	75	0.622
Vital signs							
HR (beats/min)	81	69	94	78	67	93	0.112
RR (beats/min)	20	18	21	20	18	21	0.718
MAP (mmHg)	100	87	115	101.33	87	116.67	0.639
Intervention factor							
PCI (%)	No	166	23.15%	No	82	26.71%	0.224
	Yes	551	76.85%	Yes	225	73.29%	
Risk factors							
Diabetes (%)	No	512	71.41%	No	225	73.29%	0.539
	Yes	205	28.59%	Yes	82	26.71%	
Hypertension (%)	No	354	49.37%	No	155	50.49%	0.744
	Yes	363	50.63%	Yes	152	49.51%	
Laboratory findings							
Cholesterol (mmol/L)	4.40	3.85	5.00	4.37	3.64	4.91	0.117
HDL (mmol/L)	0.96	0.86	1.07	0.95	0.86	1.06	0.881
LDL (mmol/L)	3.00	2.45	3.52	2.93	2.36	3.43	0.079
TG (mmol/L)	1.68	1.26	2.29	1.70	1.26	2.36	0.760
Chlorine (mmol/L)	104	102	106.62	105	102	107	0.148
Ionized Calcium (mmol/L)	1.18	1.14	1.22	1.19	1.13	1.23	0.379
Kalium (mmol/L)	3.90	3.60	4.20	3.90	3.60	4.10	0.542
Sodium (mmol/L)	140	139	142	141	139	143	0.056
Glucose (mmol/L)	7.80	6.40	10.40	7.40	6.10	10	0.011
APTT(s)	25.40	23.65	27.30	25.20	23.70	26.80	0.369
Fibrinogen (g/L)	3.10	2.60	4	3.10	2.60	3.70	0.162
PT(s)	10.60	10.10	11.30	10.70	10.00	11.20	0.825
INR	1	1	1.10	1	1	1.10	0.731
TT(s)	18	16	19	18	16.38	19	0.562
Urea Nitrogen (mmol/L)	5.60	4.33	7.10	5.38	4.36	6.74	0.250
Creatinine (umol/L)	75	63	96	77	63	94	0.735
UA (umol/L)	349	288	422.50	339	276	405	0.120
Albumin (g/L)	41	38	44	41	37.78	44	0.360
ALT (u/L)	27	18	42	25	17	41	0.280
Globulin (g/L)	28	25	31	27	25	30	0.733
Total Bilirubin (mmol/L)	8.90	6.38	12.69	9.30	6.80	13.30	0.301
WBC (*10^9/L)	9.77	7.99	12.26	9.36	7.68	11.96	0.105
Hematocrit (%)	0.43	0.39	0.46	0.43	0.39	0.46	0.742
Lymphocyte (*10^9/L)	1.73	1.16	2.63	1.73	1.10	2.56	0.526
PLT (*10^9/L)	225	185	263.50	205	179	247	0.001

(*Continued*)

Table 2 (Continued).

Variables	Modeling Group (n=717)			Validation Group (n=307)			P-value
	Median	P25	P75	Median	P25	P75	
Severe complication (%)	26.50%			25.41%			0.636
Death	No	684	95.40%	No	296	96.42%	0.461
	Yes	33	4.60%	Yes	11	3.58%	
HF	No	551	76.85%	No	252	82.08%	0.062
	Yes	166	23.15%	Yes	55	17.92%	
VF	No	707	98.61%	No	301	98.05%	0.508
	Yes	10	1.39%	Yes	6	1.95%	
CS	No	678	94.56%	No	285	92.83%	0.285
	Yes	39	5.44%	Yes	22	7.17%	
VT	No	703	98.05%	No	300	97.72%	0.735
	Yes	14	1.95%	Yes	7	2.28%	
AVB	No	699	97.49%	No	299	97.39%	0.929
	Yes	18	2.51%	Yes	8	2.61%	

Abbreviations: HR, heart rate; RR, respiratory rate; MAP, mean artery pressure; PCI, percutaneous coronary intervention; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglyceride; APTT, activated partial thromboplastin time; PT, prothrombin time; INR, international normalized ratio; TT, thrombin time; UA, uric acid; ALT, alanine aminotransferase; WBC, white blood cell; PLT, platelet; HF, heart failure; VF, ventricular fibrillation; CS, cardiogenic shock; VT, ventricular tachycardia; AVB, atrioventricular block.

Comparison of Baseline Data Between the Modeling Group with and without Severe Complications

Table 3 showed the comparison of baseline data between the modeling group with and without severe complications. 717 patients were included in the modeling group, including 190 cases (26.50%) in the group with severe complications and 527 cases (73.50%) in the group without severe complications. No notable variations were observed in HDL, chloride,

Table 3 Comparison of Baseline Data Between the Modeling Group with and without Severe Complications

Variables	Non-severe Complication (n=527)			Severe Complication (n=190)			P-value
	Median	P25	P75	Median	P25	P75	
Demographics							
Gender (%)	Female	110	20.87%	Female	61	32.11%	0.002
	Male	417	79.13%	Male	129	67.89%	
Age(years)	63	53	72	61.75	71	79.25	<0.001
Vital signs							
HR (beats/min)	78	68	91	88.50	72.75	106.25	<0.001
RR (beats/min)	20	18	21	20	18	22.25	0.001
MAP (mmHg)	103	89.33	116	93.50	79.25	108	<0.001
Intervention factor							
PCI (%)	No	117	21.06%	No	55	28.95%	0.027
	Yes	416	78.94%	Yes	135	71.05%	
Risk factor							
Diabetes (%)	No	405	76.85%	No	107	56.32%	<0.001
	Yes	122	23.15%	Yes	83	43.68%	
Hypertension (%)	No	286	54.27%	No	68	35.79%	<0.001
	Yes	241	45.73%	Yes	122	64.21%	

(*Continued*)

Table 3 (Continued).

Variables	Non-severe Complication (n=527)			Severe Complication (n=190)			P-value
	Median	P25	P75	Median	P25	P75	
Laboratory findings							
Cholesterol (mmol/L)	4.47	3.95	5.04	4.26	3.56	4.85	0.001
HDL (mmol/L)	0.95	0.86	1.06	0.96	0.86	1.08	0.877
LDL (mmol/L)	3.06	2.53	3.57	2.87	2.27	3.37	0.004
TG (mmol/L)	1.76	1.27	2.41	1.57	1.18	2.00	0.001
Chlorine (mmol/L)	104	102	106	104	102	107	0.747
Ionized Calcium (mmol/L)	1.19	1.14	1.23	1.16	1.12	1.20	<0.001
Kalium (mmol/L)	3.90	3.60	4.10	4	3.70	4.40	<0.001
Sodium (mmol/L)	140	139	142	140	138.97	142	0.671
Glucose (mmol/L)	7.70	6.30	9.80	9.10	7.18	12.50	<0.001
APTT(s)	25.40	23.70	27.10	25.50	23.30	28.20	0.764
Fibrinogen (g/L)	3	2.60	3.80	3.50	2.70	4.57	<0.001
PT(s)	10.50	10.10	11.10	11.10	10.40	12.05	<0.001
INR	1	1	1.03	1	1.04	1.13	<0.001
TT(s)	18	16.46	19	17	16	18.03	0.192
Urea Nitrogen (mmol/L)	5.29	4.24	6.63	6.60	5.00	8.72	<0.001
Creatinine (umol/L)	73	62	89	87.50	66.80	125.25	<0.001
UA (umol/L)	339	284	406	374	304.75	469.50	<0.001
Albumin (g/L)	42	39	44	38.50	35	42	<0.001
ALT (u/L)	26	18	38	28.50	19	52.66	0.014
Globulin (g/L)	28	25	30.19	28	24	32	0.411
Total Bilirubin (mmol/L)	8.60	6.30	12.10	9.50	6.60	14.10	0.035
WBC (*10^9/L)	9.56	7.82	11.67	10.38	8.75	13.43	<0.001
Hematocrit (%)	0.44	0.40	0.47	0.42	0.37	0.45	<0.001
Lymphocyte (*10^9/L)	1.79	1.26	2.62	1.56	0.98	2.83	0.017
PLT (*10^9/L)	225	183	263	224	188.75	268.25	0.388

Abbreviations: HR, heart rate; RR, respiratory rate; MAP, mean artery pressure; PCI, percutaneous coronary intervention; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglyceride; APTT, activated partial thromboplastin time; PT, prothrombin time; INR, international normalized ratio; TT, thrombin time; UA, uric acid; ALT, alanine aminotransferase; PLT, platelet.

sodium, APTT, TT, globulin, total bilirubin and PLT levels between the two groups (all P>0.05). The group without severe complications had lower levels of WBC, HR, kalium, glucose, fibrinogen, PT, urea nitrogen, creatinine, UA, ALT, total bilirubin and the proportion of females compared to the group with severe complications. (P<0.05). Age, MAP, cholesterol, LDL, TG, ionized calcium, albumin, hematocrit, lymphocyte, PLT and the male ratio was greater in the group without severe complications (P<0.05). Additionally, the rate of PCI treatment was significantly higher in the group without severe complications compared to those with severe complications (P < 0.05).

Multivariate Logistic Regression

Perform statistical analysis on the indicators in the modeling group through single factor binary logistic regression analysis. Twenty-five variables were screened out, including gender, age, HR, MAP, PCI, diabetes, hypertension, TG, cholesterol, LDL, ionized calcium, kalium, glucose, APTT, fibrinogen, PT, INR, urea nitrogen, creatinine, UA, albumin, ALT, total bilirubin, and WBC (P<0.05). Include all these 25 variables in a multivariate binary logistic analysis. Ultimately, variables including TG, age, HR, MAP, diabetes, hypertension and WBC were identified as independent risk factors for severe complications in AMI patients (Table 4).

Table 4 Logistic Regression Analysis of Modeling Group

	Univariate Analysis				Multivariate Analysis			
	OR	**95% CI**		**P-value**	**OR**	**95% CI**		**P-value**
Gender	0.558	0.385	0.808	0.002	0.639	0.389	1.051	0.078
Age (years)	1.049	1.034	1.064	<0.001	1.027	1.007	1.047	**0.009***
HR (beats/min)	1.015	1.008	1.023	<0.001	1.018	1.008	1.028	**<0.001***
RR (beats/min)	1.014	0.992	1.037	0.216				
MAP (mmHg)	0.979	0.971	0.986	<0.001	0.975	0.965	0.986	**<0.001***
PCI	0.655	0.449	0.955	0.028	1.154	0.722	1.845	0.550
NSTEMI	1.165	0.789	1.718	0.442				
Diabetes	2.575	1.813	3.658	<0.001	2.107	1.325	3.349	**0.002***
Hypertension	2.129	1.512	2.999	<0.001	1.717	1.123	2.624	**0.013***
Cholesterol (mmol/L)	0.797	0.679	0.935	0.005	1.433	0.752	2.730	0.275
HDL (mmol/L)	1.308	0.647	2.643	0.455				
LDL (mmol/L)	0.799	0.664	0.960	0.017	0.783	0.390	1.573	0.492
TG (mmol/L)	0.686	0.557	0.845	<0.001	0.715	0.541	0.944	**0.018***
Chlorine (mmol/L)	1.003	0.962	1.045	0.896				
Ionized Calcium (mmol/L)	0.002	0.000	0.023	<0.001	0.076	0.002	3.492	0.187
Kalium (mmol/L)	2.238	1.603	3.124	<0.001	1.469	0.943	2.288	0.089
Sodium (mmol/L)	1.012	0.964	1.062	0.627				
Glucose (mmol/L)	1.057	1.024	1.091	0.001	1.015	0.983	1.048	0.355
APTT(s)	1.054	1.017	1.093	0.004	1.018	0.979	1.058	0.366
Fibrinogen (g/L)	1.345	1.186	1.526	<0.001	0.986	0.822	1.183	0.883
PT(s)	1.462	1.269	1.684	<0.001	0.857	0.476	1.542	0.606
INR	37.612	9.405	150.411	<0.001	8.504	0.029	2453.259	0.459
TT(s)	0.950	0.874	1.033	0.228				
Urea Nitrogen (mmol/L)	1.185	1.123	1.249	<0.001	1.003	0.914	1.100	0.957
Creatinine (umol/L)	1.004	1.002	1.006	<0.001	1.001	0.998	1.003	0.578
UA (umol/L)	1.003	1.002	1.005	<0.001	1.002	1.000	1.004	0.077
Albumin (g/L)	0.872	0.841	0.905	<0.001	0.984	0.919	1.054	0.651
ALT (u/L)	1.004	1.001	1.007	0.013	1.000	0.998	1.002	0.954
Globulin (g/L)	1.023	0.988	1.059	0.204				
Total Bilirubin (mmol/L)	1.025	1.004	1.045	0.017	1.008	0.983	1.034	0.518
WBC (*10^9/L)	1.095	1.050	1.142	<0.001	1.078	1.015	1.144	**0.014***
Hematocrit (%)	0.002	0.000	0.034	<0.001	6.039	0.080	456.343	0.415
Lymphocyte (*10^9/L)	0.995	0.886	1.119	0.939				
PLT (*10^9/L)	1.002	0.999	1.004	0.172				

Note: *P<0.05 means statistical significance.

Abbreviations: HR, heart rate; RR, respiratory rate; MAP, mean artery pressure; PCI, percutaneous coronary intervention; NSTEMI, non-ST-segment elevation myocardial infarction; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglyceride; APTT, activated partial thromboplastin time; PT, prothrombin time; INR, international normalized ratio; TT, thrombin time; UA, uric acid; ALT, alanine aminotransferase; PLT, platelet; OR, odds ratio; CI, confidence interval.

Model Establishment (Nomogram)

Depending on what the modelling group's multivariate logistic analysis revealed, TG, age, HR, MAP, diabetes, hypertension and WBC were ultimately identified as independent risk factors for severe complications in AMI patients. Establish a nomogram through R software package programming (Figure 2).

There are seven variables in a nomogram: TG, age, HR, MAP, diabetes, hypertension and WBC. With the use of charts, we can clearly show the relationships between each variable in this graphical representation of the statistical model. The probability that patients may experience major problems increases with a nomogram score.

For example, we used a simple random sampling method to analyze the clinical data of two AMI patients.

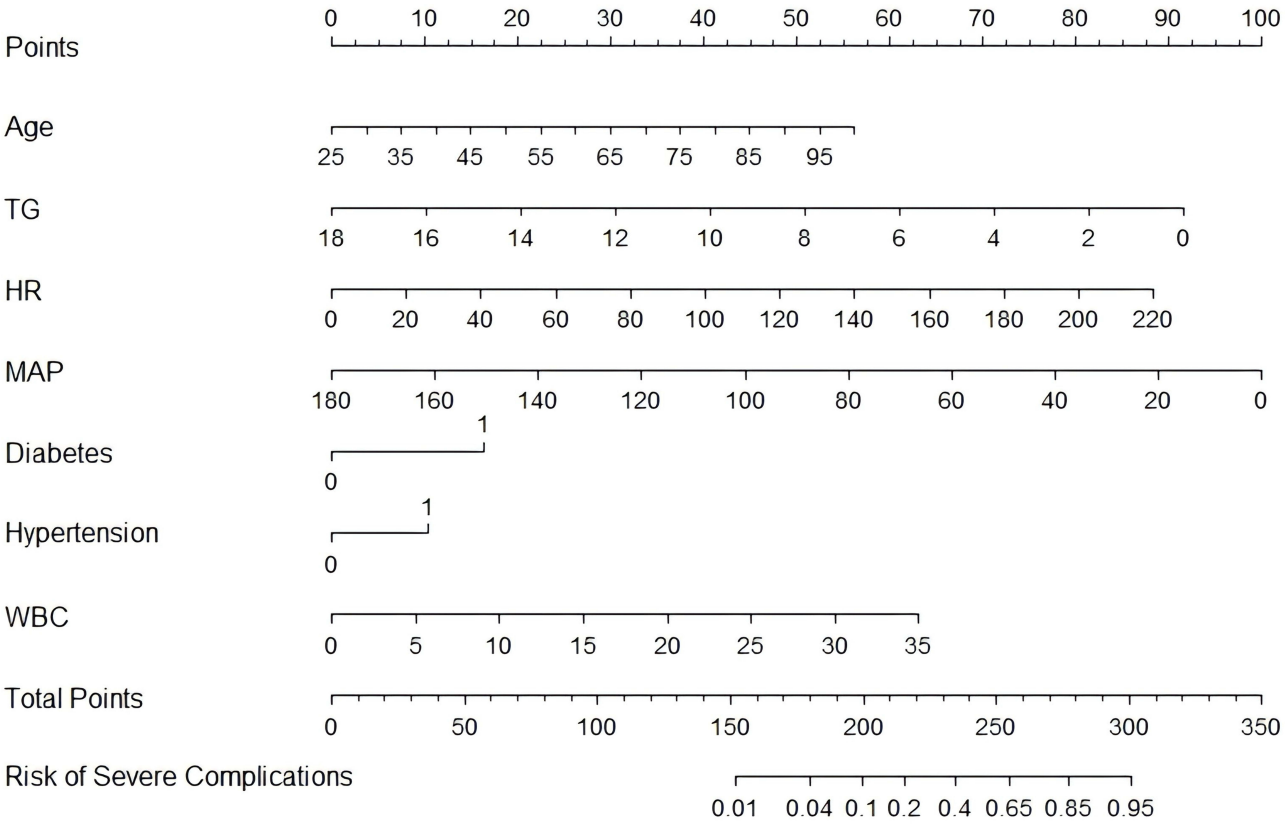

Figure 2 Nomogram.
Abbreviations: TG, triglyceride; HR, heart rate; MAP, mean artery pressure; WBC, white blood cell.

The first patient clinically diagnosed with AMI was TG: 1.17 (87.5 points), Age: 67 years old (32.5 points), HR: 112 (47.5 points), MAP (SBP: 120, DBP: 86): 97.33 (45 points), WBC: 13.50 (22.5 points), with Diabetes (17.5 points) and Hypertension (10 points). The above scores were added up to a total of 262.50 points. The risk of severe complications after AMI corresponding to 262.50 points was identified in the nomogram, and the probability of serious complications in the patient was predicted to be greater than 70%, In actual clinical practice, patients are transferred to the intensive care unit due to serious complications after myocardial infarction. The predicted results are consistent with the actual clinical manifestations of the patient.

Another patient clinically diagnosed with AMI: TG: 14.62 (20 points), Age: 56 years old (22.5 points), HR: 106 (42.5 points), MAP (SBP: 124, DBP: 84): 97.33 (45 points), WBC: 9.44 (17.5 points), without Diabetes (0 points) or Hypertension (0 points). The above scores were added up to a total of 147.50 points. The risk of serious complications after AMI corresponding to 147.50 points was identified in the nomogram, and the probability of serious complications in the patient was predicted to be less than 1%. In actual clinical practice, the patient recovered and was discharged within one week without any serious complications. The predicted results are consistent with the actual clinical manifestations of the patient.

Validation of Column Charts' Prediction Accuracy in Modeling and Validation Queues

With an AUC=0.791 (95% CI: 0.753–0.829), the predictive model in the modeling group demonstrated high accuracy in estimating the probability of serious complications in AMI patients (Figure 3).

Using the repeated sample approach (n=717, sampling frequency=1000) in R software, internal validation was carried out with an absolute error of 0.011. Additionally, by creating calibration curves, we assess the optimal model's predictive ability. The ideal model's flawless prediction is shown by the diagonal dashed line among them. The nomogram's performance is

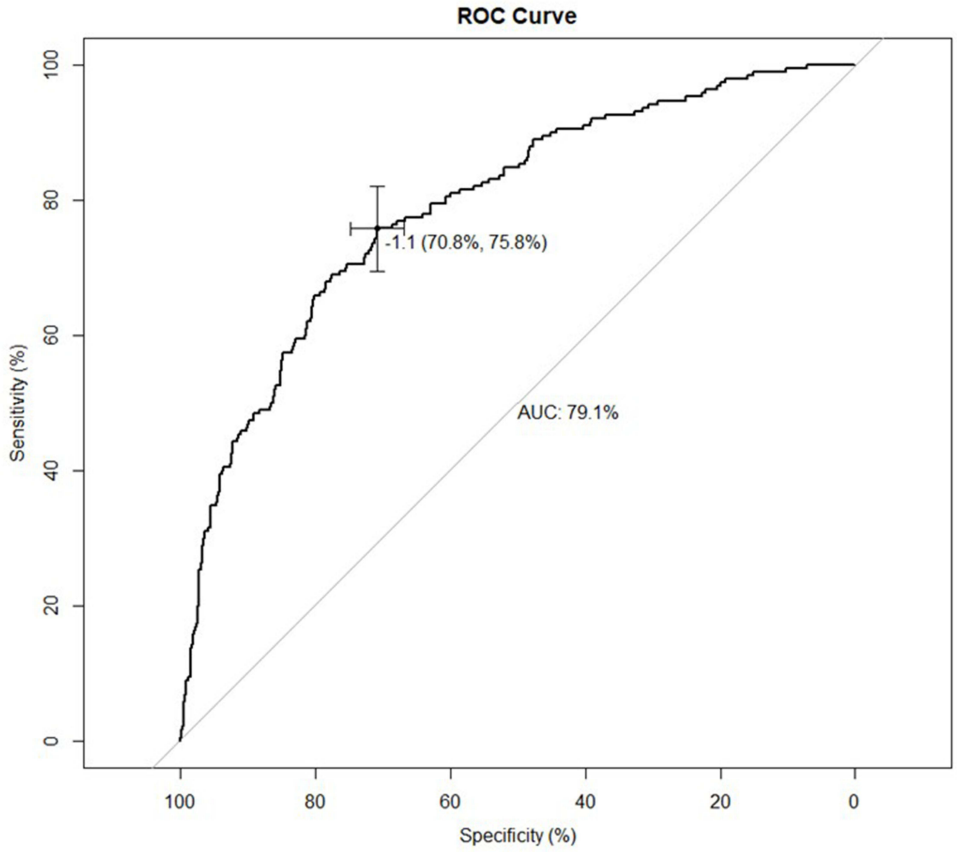

Figure 3 Validation of nomogram in the modelling group, AUC=0.791 (95% CI: 0.753–0.829).
Abbreviation: AUC, the area under the receiver operating characteristic curve.

shown by the solid line; the stronger the prediction effect, the higher the fit with the diagonal (dashed line). The model has high calibration, as evidenced by the good consistency between the projected and actual models (Figure 4).

The validation queue similarly confirmed the prediction model's accuracy, with an AUC = 0.732 (95% CI: 0.661–0.803) (Figure 5).

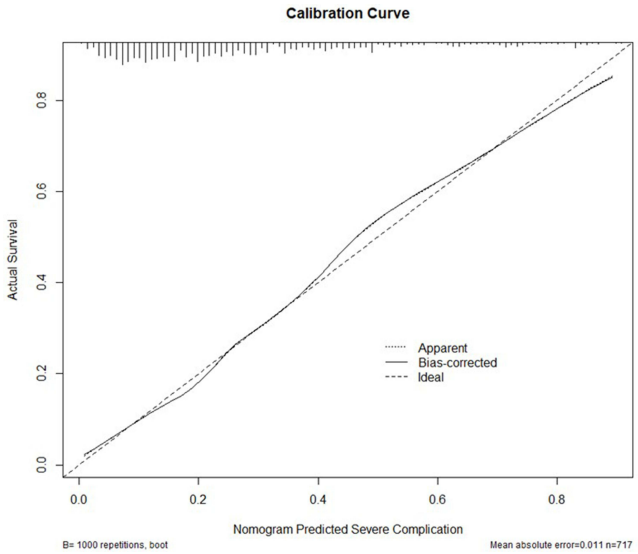

Figure 4 Nomogram calibration curve. Internal validation (n=717, sampling frequency=1000) with an absolute error of 0.011).

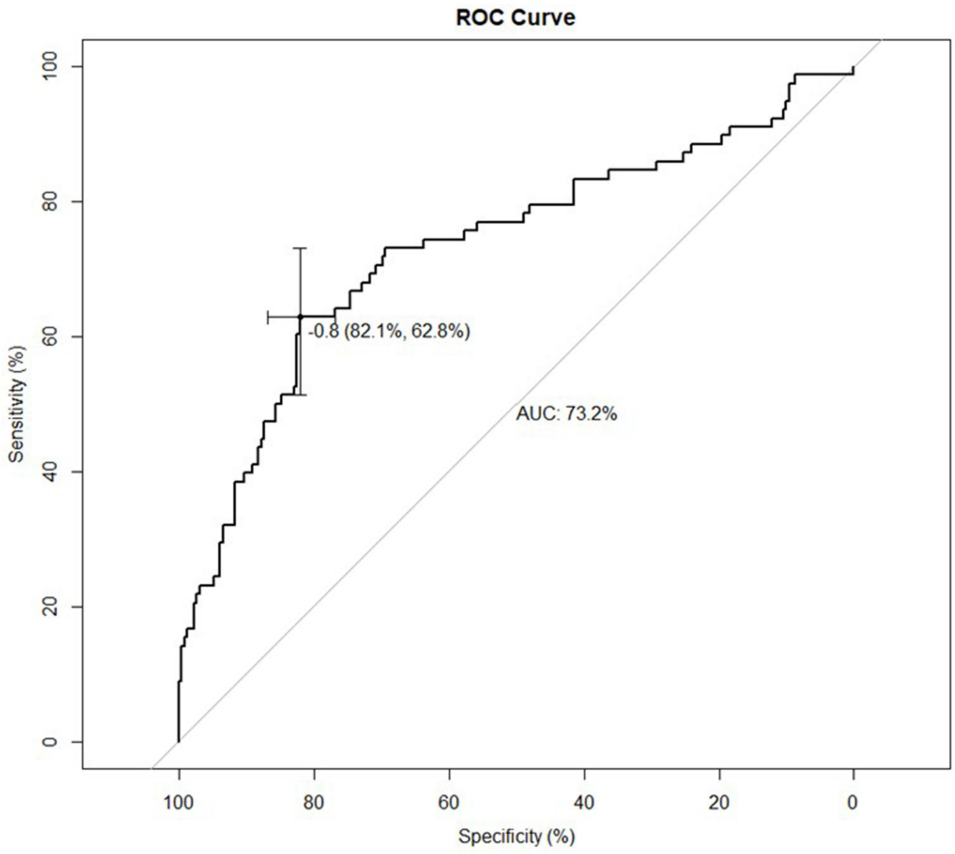

Figure 5 Validation of nomogram in the validation group. AUC = 0.732 (95% CI: 0.661–0.803).
Abbreviation: AUC, the area under the receiver operating characteristic curve.

Internal validation was conducted using R software repeated sampling method (n=307, sampling frequency=1000), with an absolute error of 0.044; And draw a calibration curve, The findings indicate that the model's calibration is good because there is a rather strong agreement between the expected probability and the observed probability (Figure 6).

Evaluation of DCA Curve Model

Drawing DCA curves with the R 42.2 software program to assess the prediction model's net benefit reveals that the model has a broad threshold range (0.01~0.73), a good clinical net benefit, and good applicability in clinical practice (Figure 7).

Discussion

AMI is a severe cardiovascular disease that contributes significantly to global incidence and mortality rates. By conducting early assessments of the likelihood of serious complications in AMI patients, we can accurately pinpoint those requiring focused attention and prompt intervention to achieve improved clinical outcomes. This research incorporated age, HR, MAP, diabetes, hypertension, TG, and WBC as seven separate risk factors in creating a nomogram model that can forecast the likelihood of severe complications in patients with AMI, showcasing robust clinical predictive ability.

Our study found that patients with severe complications had a significantly higher WBC counts compared to those without severe complications. Previous evidence has indicated WBC, as biomarkers associated with systemic inflammatory response, plays a clear role in both the development and resolution of inflammation during AMI.[11] Our research findings support the correlation between elevated levels of WBC and a negative prognosis in individuals suffering from

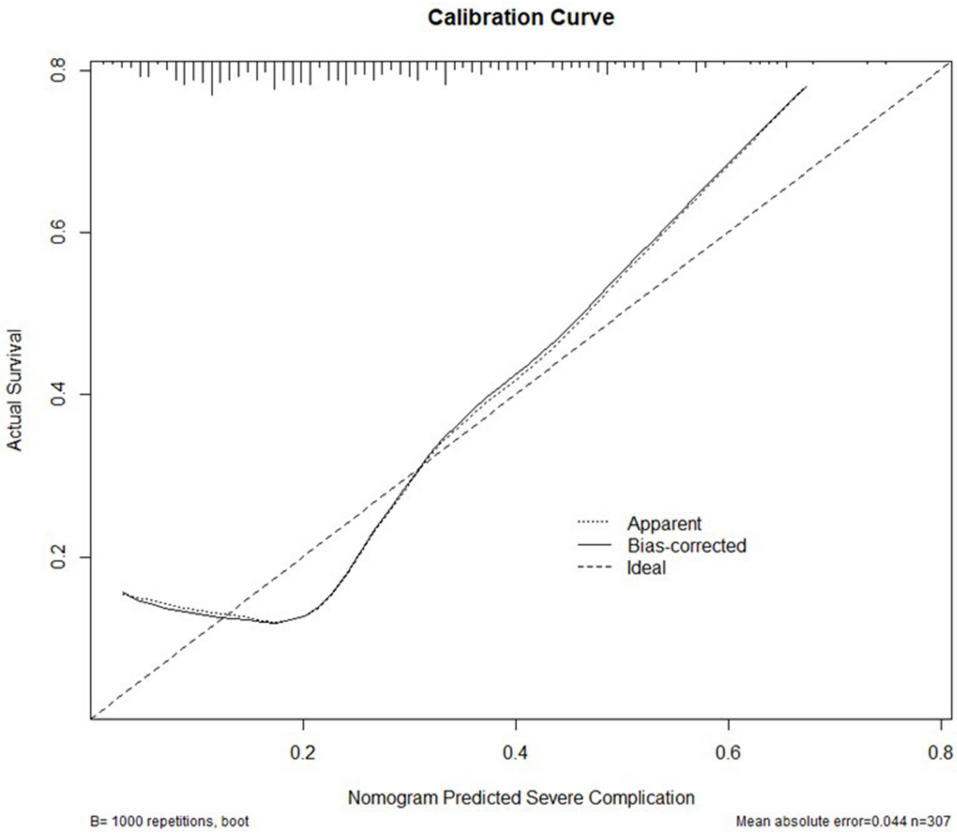

Figure 6 Nomogram calibration curve. Internal validation (n=307, sampling frequency=1000) with an absolute error of 0.044).

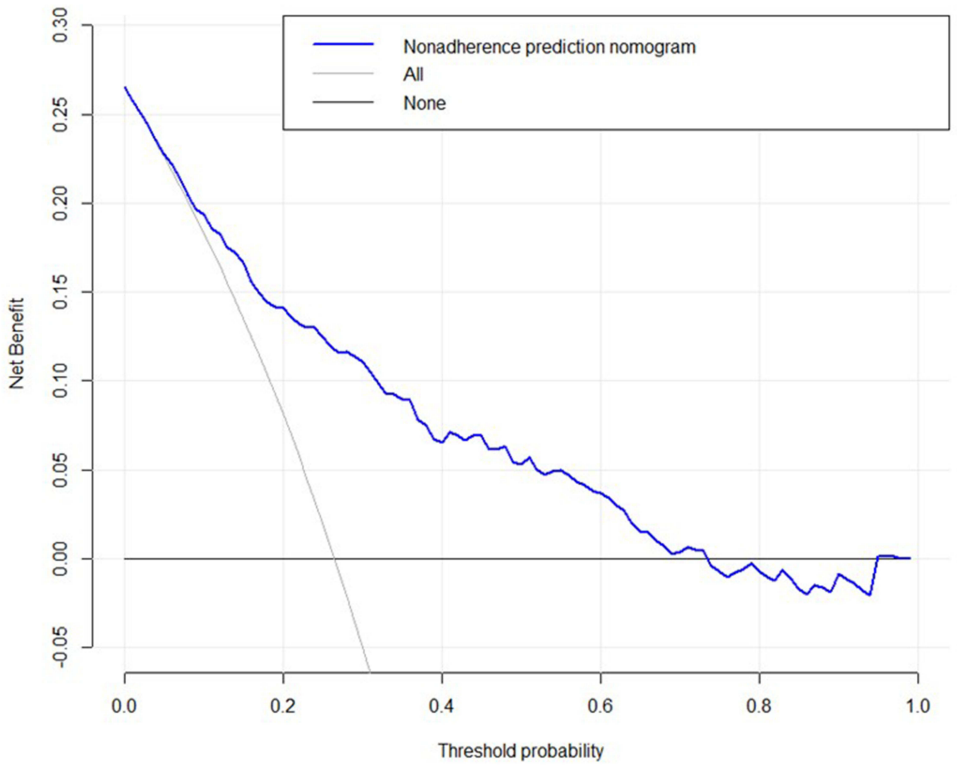

Figure 7 DCA curves of the prediction model.
Abbreviation: DCA= decision curve analysis.

AMI. The increase in WBC counts in circulation can lead to the release of various proteolytic enzymes that worsen local tissue damage,[12] ultimately impacting myocardial remodeling and potentially leading to catastrophic consequences.[13]

Hypertriglyceridemia has traditionally been recognized as a risk factor for cardiovascular disease.[14] Research indicates that elevated TG levels can heighten the likelihood of cardiovascular disease.[15] Conversely, low TG levels are not conducive to maintaining the stability of cell membranes.[16] As a result, the relationship between TG and cardiovascular disease risk has been a topic of debate. Recent studies have revealed a negative association between TG levels and adverse outcomes in patients with cardiovascular and cerebrovascular diseases.[17–20] For instance, low serum TG levels have been found to have a negative correlation with in-hospital death and late outcomes in patients with ST-elevation myocardial infarction (STEMI) who are treated with PCI,[17] Additionally, a decrease in serum TG levels has been identified as a predictor of cardiovascular death in individuals with HF.[21] The reduction in TG during acute coronary syndromes is correlated with a rise in the occurrence of recurrent ischemia.[22] This has led to the emergence of the "TG paradox" concept. Our research focused on examining the relationship between TG levels upon admission and the likelihood of severe complications in individuals diagnosed with AMI. The results of our study revealed an inverse association between TG levels and the potential for significant complications in patients suffering from AMI.

Older age has been identified as a major risk factor for developing acute coronary syndrome, and it is also associated with a higher probability of experiencing negative clinical outcomes.[23] As individuals age, the incidence of cardiovascular and cerebrovascular diseases tends to increase.[24] Research has shown that individuals aged 65–74 have almost a sevenfold increased risk of experiencing a heart attack compared to those in the 35–44 age bracket.[25] With aging, the arterial wall becomes thicker and harder, leading to an increased risk of cardiovascular disease.[26,27] Our research aligns with these findings, demonstrating a strong age dependence in cardiovascular disease.

The heart rate (HR) plays a crucial role in determining the oxygen demand of the heart muscle, affecting the flow of blood through the coronary arteries by impacting the time for filling the heart during its resting phase. The importance of HR as a prognostic factor in individuals with heart-related conditions such as heart attacks, high blood pressure, and heart dysfunction is well-known.[28–30] Several studies have emphasized the role of HR as a predictor of mortality and the onset of cardiovascular disorders like high blood pressure, heart dysfunction, and heart artery blockage.[31–33] Research indicates that in individuals experiencing a heart attack, higher heart rates are linked to an increased risk of cardiovascular-related death.[34,35]

MAP is a predictive indicator of all-cause and cardiovascular disease mortality in middle-aged and elderly individuals. Higher levels of MAP are associated with target organ damage, cardiovascular disease, and cerebrovascular disease.[36–40] However, some studies have shown that patients with low MAP in AMI are more likely to experience left ventricular dysfunction.[41] This finding aligns with our own research.

Diabetes has been recognized as a risk factor for AMI and is a common complication among AMI inpatients.[42] Researches indicated that diabetes could increase the risk of AMI by two to four times.[43] Additionally, elevated blood glucose levels can contribute to various risk factors, for example, hinder the clearance of TG-rich lipoproteins in the bloodstream. Individuals with inadequately managed diabetes have elevated TG levels in contrast to those with well-managed diabetes. Additionally, there seems to be an extended duration of postprandial hyperlipidemia in diabetic individuals, suggesting prolonged exposure of arteries to atherogenic particles.[44] Our study additionally affirms the idea that diabetes heightens the likelihood of severe complications in individuals with a heart attack.

Hypertension is a significant global cardiovascular risk factor that is strongly linked to coronary artery disease. The prevalence of hypertension is high and tends to increase with age.[45] The pathological and physiological links between hypertension and AMI involve endothelial dysfunction, autonomic nervous system dysfunction, impaired vascular reactivity, and genetic factors.[46] Research shows that approximately 30–40% of patients with STEMI have hypertension, while the rate is even higher at around 70% for those with non-ST segment elevation myocardial infarction (NSTEMI).[47,48] Our research findings align with this conclusion.

Previously researches mainly focused on the predicting single prognostic outcomes after AMI attack such as death,[49] heart failure[50,51] and so on. However, our study constructed a model which could predict various severe complications including acute circulatory dysfunction, severe arrhythmia, heart failure, and death after AMI. In addition, the sample size used in this study (n=1024) is relatively large, and all variables involved are commonly used indicators in clinical laboratory tests and general information of patients, with good clinical applicability.

This research has limitations that must be considered. Firstly, as a study conducted at a single center, it is crucial to recognize the necessity of adjusting for differences in countries, regions, and populations when utilizing the nomogram. When validating the model on a larger scale or in other centers, it is crucial to consider the diversity in etiologies and lifestyle habits across different regions. Secondly, conducting multicenter studies with larger sample sizes is essential to validate our findings. Secondly, the retrospective nature of our study introduces potential patient selection bias, a common limitation in such studies. Thirdly, a more comprehensive analysis comparing patient age and different types of myocardial infarction would enhance the representativeness of our research results. Fourthly, we compared the risk of severe complications in patients with AMI who underwent PCI and those who did not. However, we all know that the key to early treatment of AMI is to rebuild the infarcted blood vessel, so early PCI is crucial. Our study only focused on whether the patient underwent PCI or not. Due to the data missing, we could not compare the impact of different times of PCI on the occurrence of severe complications after AMI. Relevant studies have proved that the recovery of left ventricular ejection fraction after AMI is associated with better prognosis.[52–56] However, our study lacks relevant data on left ventricular function at the initial stage and after MI, which leads to a certain limitation in our study.

Conclusion

The column chart prediction model developed based on the above seven independent risk factors has strong discriminative ability and good clinical practicality. Clinical doctors can quickly and easily assess the risk of serious complications for AMI patients upon admission through easily accessible data, and intervene early to reduce the occurrence of adverse events.

Data Sharing Statement

Datasets used and/or analyzed in the present study were availed by the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was conducted in accordance with Declaration of Helsinki 2002. The study was approved by institutional review board of Changsha Central Hospital of University of South China (NO.2023-045 KTSB). Due to retrospective characteristics of the study, informed consent was waived. All patient information was anonymous and confidential.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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