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Prediction model of in-hospital mortality in elderly patients with acute heart failure based on retrospective study

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Abstract

Objectives The aim of this study was to develop a clinical risk model that is predictive of in-hospital mortality in elderly patients hospitalized with acute heart failure (AHF). **Methods** 2486 patients who were 60 years and older from intensive care units of Cardiology Department in the hospital were analyzed. Independent risk factors for in-hospital mortality were obtained by binary logistic regression and then used to establish the risk prediction score system (RPSS). The area under the curve (AUC) of receiver operator characteristic and C-statistic test were adopted to assess the performance of RPSS and to compare with previous get with the guidelines–heart failure (GWTG-HF). **Results** By binary logistic regression analysis, heart rate (OR: 1.043, 95% CI: 1.030–1.057, $P < 0.001$), left ventricular ejection fraction (OR: 0.918, 95% CI: 0.833–0.966, $P < 0.001$), pH value (OR: 0.001, 95% CI: 0.000–0.002, $P < 0.001$), renal dysfunction (OR: 0.120, 95% CI: 0.066–0.220, $P < 0.001$) and NT-pro BNP (OR: 3.463, 95% CI: 1.870–6.413, $P < 0.001$) were independent risk factors of in-hospital mortality for elderly AHF patients. Additionally, RPSS, which was composed of all the above-mentioned parameters, provided a better risk prediction than GWTG-THF (AUC: 0.873 *vs*. 0.818, $P = 0.016$). **Conclusions** Our risk prediction model, RPSS, provided a good prediction for in-hospital mortality in elderly patients with AHF.

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Keywords: Acute heart failure; In-hospital mortality; Prediction model; Risk factors

1 Introduction

Heart failure (HF) is one of the most burgeoning healthcare problems in Cardiology Department. It causes considerable morbidity and mortality, the frequency of hospitalization for HF has been increasing in recent years. In several published registries, in-hospital mortality of HF patients ranges from 4% to 7%.[1–3] Most patients with HF are elderly, constituting up to 80% of patients suffering from this disease, both the incidence and prevalence of HF increase with age.[4] In patients with HF, age is associated with an increased risk of cardiovascular events and mortality during short- and long- term follow-up.[5,6]

Clinical risk prediction tools may be helpful in guiding medical decision making and improving prognosis. Previous studies generally based on outpatients with chronic heart failure (CHF), have identified a number of variables that are associated with increased mortality. Patients with CHF may readmit for acute heart failure (AHF). During hospital admissions for AHF, the majority of patients' symptoms are relieved. However, not all patients recover well. Despite standard initial therapy, some subsets of patients experience worsening heart failure (WHF) or even death that is inevitable during hospitalization.

Early identification of risk factors that accelerate in-hospital mortality may improve prognosis and aid in decision making. Although there are several in-hospital mortality prediction models available, data on such prediction models in elderly patients is limited. For example, the American Heart Association get with the guidelines–heart failure (GWTG-HF) program risk score was established based on a large sample size, however, it was not validated

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in a separate population (e.g. elderly patients). Acute physiology and chronic health evaluation (APACHE Ⅱ) is another scoring system that is used to assess the severity of the disease. However, it contains too many parameters to make it easy to use. Although age is an independent risk factor in patients with HF,[7] there are few studies on risk prediction models for elderly patients. Therefore, the objective of the present study was to develop a risk stratification practice method for in-hospital mortality among elderly patients who were admitted with AHF; this method is applicable in routine clinical practice.

2 Methods

2.1 Patient population and study design

This retrospective study was performed in intensive care units of the Cardiology Department in the Chinese PLA General Hospital. For the purpose of our study, diagnosis of AHF was made according to the inclusion criteria from the European Society of Cardiology according to symptoms or signs, electrocardiogram, chest radiograph, and echocardiography.[8] Patients were identified for inclusion in the study from admission when given a diagnosis of AHF based on International Classification of Diseases, Ninth/Tenth Revision (ICD-9/10) coding from 2003 January to 2016 October (n = 3026). The exclusion criteria included the following: younger than 60 years old (n = 295), malignant tumors (n = 23), acute coronary syndrome (n = 174), acute cerebrovascular diseases within the past three months (n = 37), immunological diseases (n = 11) and other patients in any case that were not suitable for this study.

According to the criteria mentioned above, 2486 patients who were 60 years and older with AHF in intensive care units of the Chinese PLA General Hospital were screened, and 55 patients were excluded for missing data. The study population was randomly divided into derivation (70%, n = 1702) and validation (30%, n = 729) groups.[9] AHF patients were grouped according to the outcomes. Flow chart of study participants was shown in Figure 1. Patients' demographic and baseline characteristics, past medical history, clinical presentation, treatments, laboratory tests, and outcomes during admission were recorded. The study was approved by the Ethical Committee for Medical Research of Chinese PLA General Hospital.

2.2 Statistical analysis

All statistical operations in this study were completed by the Department of Statistics of Peking University Health Science Center. The normal distribution test for continuous variables was conducted using the Kolmogorov-Smirnov test. Continuous variables were presented as the mean ± SD or median (25^{th}–75^{th} percentiles) according to normality. Statistical analysis of normal distribution data was performed using an unpaired Student's t-test between two groups. Non-normal distribution data were analyzed using the Mann-Whitney U test for continuous variables and the χ^2 test for discrete variables. Multivariate analysis was conducted using binary logistic regression. Statistical results are expressed as odds ratios (OR) and 95% confidence intervals (CI). We used the forward method to exclude insignificant variables. The receiver operator characteristic curve (ROC) of significant variables and C-statistic testing were utilized to assess the performance of the constructed model in comparison with a previously published model. All tests were carried out using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA) and MedCalc version 15.6.1 (MedCalc

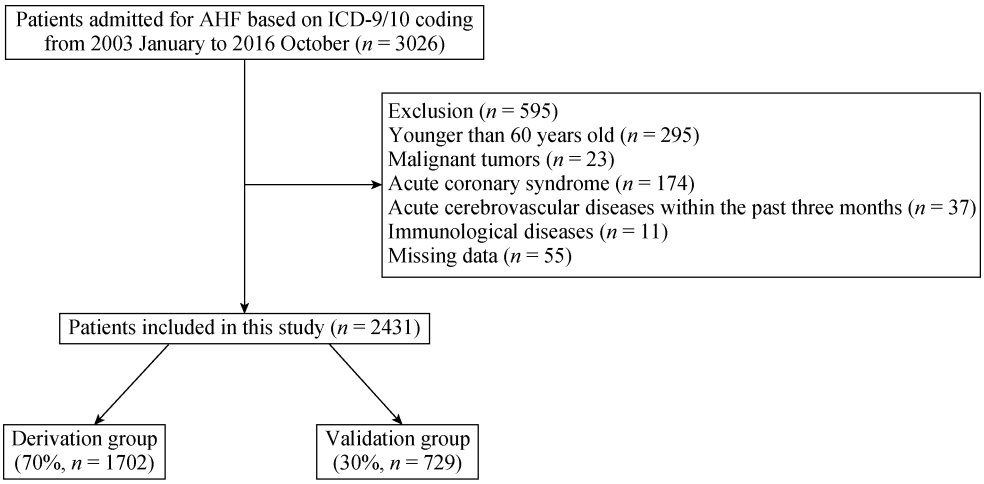

Figure 1. Flow chart of study participants (n = 2431). AHF: acute heart failure; ICD: international classification of diseases.

Software, Mariakerke, Belgium) statistical software. Differences were considered statistically significant at a two-tailed *P* value of less than 0.05.

3 Results

In total, 2431 patients with AHF were included in this retrospective study. Based on the grouping method of a previous study, 2431 patients were randomly divided into derivation (70%, $n = 1702$) and validation (30%, $n = 729$) groups.[9]

The baseline characteristics, physiological parameters and management of patients in the derivation group are shown in Table 1. A total of 1702 patients were included. They were divided into two groups according to their outcomes during hospitalization. In total, 90 patients who died and 1612 who survived during hospitalization were included. The two groups were similar with respect to age, sex distribution, systolic blood pressure, diastolic blood pressure and body mass index. In the past medical history, patients dying during hospital stay had a great number of pulmonary infection (57.77% *vs*. 37.47%, $P < 0.001$) compared with patients surviving during hospitalization. Serum creatinine, blood[9] urea nitrogen (BUN) and NT-pro BNP were much higher in the deceased group while the pH value and standard HCO_3 were significantly decreased. The echocardiographic results showed that left ventricular ejection fraction (LVEF) and fractional shortening (FS) were decreased in patients dying during hospital stay, indicating changes in left ventricular function. Regarding management and drug treatment, patients dying during hospital stay received more asthma drugs, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker (ACEI/ARB), morphine and vasoactive drugs during hospitalization.

According to the results presented in Table 1, heart rate (HR), respiratory rate (RR), aspartate aminotransferase (AST), eGFR (calculated by MDRD method), NT-pro BNP, pH value, HCO_3^-, left ventricular diastolic diameter (LVDD), left ventricular systolic diameter (LVSD), LVEF, FS and past history of cardiomyopathy, pulmonary infection, and chronic kidney disease were entered into a multivariable logistic regression model. The significant variables included HR (OR: 1.043, 95% CI: 1.030–1.057, $P < 0.001$), LVEF (OR: 0.918, 95% CI: 0.873–0.966, $P = 0.001$), pH value (OR: 0.001, 95% CI: 0.000–0.002, $P < 0.001$), eGFR (OR: 0.120, 95% CI: 0.066–0.220, $P < 0.001$), and NT-pro BNP (OR: 3.463, 95% CI: 1.870–6.413, $P < 0.001$) (Table 3).

All patients were stratified according to quartiles of HR (Q1, 43.00 to 75.00; Q2, 76.00 to 83.00; Q3, 84.00 to 103.00; and Q4,104.00 to 166.00), pH value (Q1, 6.785 to 7.366; Q2, 7.367 to 7.400; Q3, 7.401 to 7.435; and Q4, 7.436 to 7.524), eGFR (Q1, 24.40 to 33.47; Q2, 33.48 to 63.07; Q3, 63.08 to 86.65; and Q4, 86.66 to 120.24) and NT-pro BNP (Q1, 950.5 to 2257.5; Q2, 2257.6 to 5737.5; Q3, 5737.6 to 9369.5; and Q4, 9369.6 to 3,5000). The clinical outcomes of each quartile group are shown in Figure 2. (A–E). The incidence of patients in the deceased group for Q1 was higher than the other three groups according to the pH value and eGFR, while the incidence of the deceased group in Q1 was the lowest according to HR and NT-pro BNP. Furthermore, the incidence of patients dying during hospitalization with reduced LVEF was higher than that of patients with preserved LVEF. Acid-base imbalance often occurs in HF patients, and the pH value is an excellent warning indicator of adverse cardiac events. Figure 3. (A–C) shows the distribution of the pH values for all patients.

Using the various indicators of the ROC curve (Figure 4), we calculated Youden's index to determine the cutoff value of each index (Table 3). We established a risk prediction model of adverse cardiac events and obtain the probability of adverse cardiac events according to different values of the independent variable as shown in Table 3. We established the following in-hospital mortality prediction algorithm (PA): logit (P) = 78.023 + 0.042 × HR − 0.085 × LVEF − 6.028 × pH − 2.118 × eGFR + 1.242 × NT pro-BNP. The closer the *P* value is to 1, the greater the likelihood of adverse cardiac events. To facilitate clinical practice, we used the five independent risk factors selected by binary logistic regression to establish a Risk Prediction Score System (RPSS).[10,11] According to the OR value of the independent risk factors screened by logistic regression for in-hospital mortality, the risk factors were assigned, the non-integral OR values were taken from four to five, and the corresponding risk integral values of risk factors were obtained (Table 4).

The GWTG-HF risk score uses routinely collected clinical data to predict the risk of in-hospital mortality for patients hospitalized with HF. Age, systolic blood pressure, and BUN are the admission variables that are most predictive of in-hospital mortality; admission heart rate, serum sodium, chronic obstructive pulmonary disease (COPD) presence, and nonblack race contribute modestly. We calculated the GWTG-HF score for all patients. To assess the prediction effectiveness of PA and RPSS, we compared the ROC curves of the three methods. The area under the ROC curve values for RPSS, PA and GWTG-HF were 0.873, 0.829, and 0.818, respectively (Figure 5). The cut-off of the

Table 1. Characteristics of patients in derivation group.

	Patients dying during Hospital stay (*n* = 90)	Patients surviving during Hospital stay (*n* = 1612)	*P*-value
Age	75.35 ± 6.73	72.27 ± 7.82	0.168
Male	47 (52.22%)	813 (50.43%)	0.167
Medical history			
Coronary Heart Disease	46 (51.11%)	825 (51.19%)	0.990
Cardiomyopathy	8 (8.89%)	79 (4.80%)	0.154
Hypertension	47 (52.22%)	913 (56.64%)	0.411
Pulmonary infection	52 (57.77%)	604 (37.47%)	< 0.001
Valvular Heart disease	13 (14.44%)	204 (12.66%)	0.620
Pulmonary hypertension	7 (7.78%)	111 (6.89%)	0.746
Diabetes	31 (34.44%)	558 (34.62%)	0.974
Chronic kidney disease	30 (33.33%)	419 (25.99%)	0.124
Arrhythmia	22 (24.44%)	486 (30.15%)	0.250
Hyperlipidemia	7 (7.78%)	205 (12.72%)	0.167
Physical examination			
HR, beats/min	92.00 (79.00–108.00)	81.00 (73.00–96.00)	0.027
RR, breaths/min	21.00 (16.00–23.00)	18.00 (17.00–20.00)	0.002
SBP, mmHg	131.00 ± 26.00	127.00 ± 23.00	0.635
DBP, mmHg	78.00 ± 17.00	74.00 ± 15.00	0.752
BMI, kg/m^2	23.70 ± 6.63	24.75 ± 7.93	0.367
Biochemical			
ALT, U/L	24.50 (13.80–37.90)	17.50 (11.80–22.80)	0.073
AST, U/L	29.50 (19.20–54.60)	22.50 (16.33–28.69)	0.038
γ-GT, U/L	40.30 (24.80–71.00)	31.70 (21.83–68.30)	0.255
Cr, umol/L	132.80 (90.70–246.00)	84.20 (65.83–125.80)	< 0.001
BUN, mmol/L	12.33 (7.29–18.58)	7.28 (5.20–10.29)	0.015
Uric acid, umol/L	380.60 (281.00–476.80)	365.35 (294.80–461.73)	0.735
TG, mmol/L	1.13 (0.86–1.72)	1.24 (0.88–1.85)	0.192
T-CH, mmol/L	3.82 (3.25–4.60)	3.86 (3.19–4.65)	0.220
HDL, mmol/L	0.95 (0.73–1.22)	1.00 (0.80–1.28)	0.964
LDL, mmol/L	2.25 (1.61–2.84)	2.31 (1.81–2.85)	0.334
CK, U/L	73.60 (42.10–162.1)	77.60 (39.85–164.25)	0.866
c-TnT. ng/L	0.04 (0.01–0.16)	0.05 (0.02–0.19)	0.941
NT-pro BNP, pg/ml	12171.21 (2585.08–20885.10)	3537.39 (1140.15–6904.50)	0.019
Hemoglobin, g/L	124.00 (100.00–135.00)	120.00 (99.00–136.00)	0.738
RBC, 10^{12}/L	4.19 (3.43–4.65)	4.00 (3.39–4.45)	0.436
WBC, 10^9/L	7.26 (5.62–10.03)	7.64 (5.91–9.28)	0.788
PLT, 10^9/L	186.00 (140.00–244.00)	186.50 (135.25–238.00)	0.621
ABG			
pH value	7.35 (7.32–7.42)	7.39 (7.38–7.44)	< 0.001
PaO_2, mmHg	84.27 (60.00–99.60)	80.21 (61.60–90.28)	0.316
$PaCO_2$, mmHg	37.42 (32.03–41.48)	37.72 (32.03–41.48)	0.388
HCO_3, mmol/L	21.02 (18.00–23.60)	22.50 (19.80–24.90)	0.001
SaO_2, %	92.47 (91.10–97.90)	93.72 (92.58–97.40)	0.303
Echocardiographic			
LVDD, mm	52.64 (46.00–59.00)	50.69 (45.00–57.00)	0.050
LVSD, mm	40.83 (33.00–48.00)	37.96 (31.00–44.00)	< 0.001
LVEF, %	38.84 (30.00–45.00)	48.66 (38.00–58.00)	< 0.001
FS, %	20.37 (16.00–23.00)	25.48 (20.00–30.00)	< 0.001

Data were presented as mean ± SD, *n* (%) or median (25th–75th percentiles). ABG: arterial blood gas; ALT: alanine transferase; AST: aspartate aminotransferase; BUN: blood urea nitrogen; BMI: body mass index; CK: creatine kinase; c-TnT: cardiac troponin T; Cr: creatinine; DBP: diastolic blood pressure; FS: fractional shortening; HR: heart rate; HDL: high density lipoprotein; LDL: low density lipoprotein; LVDD: left ventricular diastolic diameter; LVSD: left ventricular systolic dysfunction; LVEF: left ventricular ejection fraction; NT-pro BNP: N-terminal pro-b-type natriuretic peptide; PLT: platelets; PH: potential of hydrogen; PaO_2: partial pressure of O_2; $PaCO_2$: partial pressure of CO_2; RR: respiratory rate; RBC: red blood count; SBP: systolic blood pressure; TG: triglyceride; T-CH: total cholesterol; WBC: white blood count; γ-GT: γ-glutamyl transpeptidase.

Table 2. Binary logistic regression model.

Factors	B	SE	Wals	df	*P* value	OR	95% CI	
HR, beats/min	0.042	0.007	40.050	1	0.000	1.043	1.030	1.057
LVEF, %	–0.085	0.026	11.000	1	0.001	0.918	0.873	0.966
pH value	–6.028	4.737	11.450	1	0.001	0.001	0.000	0.002
eGFR, mL/min/1.73 m^2	–2.118	0.308	47.326	1	0.000	0.120	0.066	0.220
NT-pro BNP, pg/mL	1.242	0.314	15.608	1	0.000	3.463	1.870	6.413

CI: confidence interval; eGFR: estimated glomerular filtration rate; HR: heart rate; LVEF: left ventricular ejection fraction; NT-pro BNP: N-terminal pro-b-type natriuretic peptide; OR: odds ratios; SE: standard error.

Table 3. Areas under the ROC curve for the following five variables: HR, LVEF, pH value, eGFR and NT-pro BNP.

Factors	Area	SE	*P* value	95% CI		Youden's index
HR, beats/min	0.733	0.022	0.000	0.736	0.822	0.361
LVEF, %	0.723	0.022	0.000	0.678	0.765	0.393
pH value	0.681	0.026	0.000	0.628	0.731	0.385
eGFR, mL/min/1.73 m^2	0.773	0.022	0.000	0.737	0.807	0.471
NT-pro BNP, pg/mL	0.720	0.025	0.000	0.672	0.769	0.409

CI: confidence interval; eGFR: estimated glomerular filtration rate; HR: heart rate; LVEF: left ventricular ejection fraction; NT-pro BNP: N-terminal pro-b-type natriuretic peptide; OR: odds ratios; ROC: receiver operator characteristic; SE: standard error.

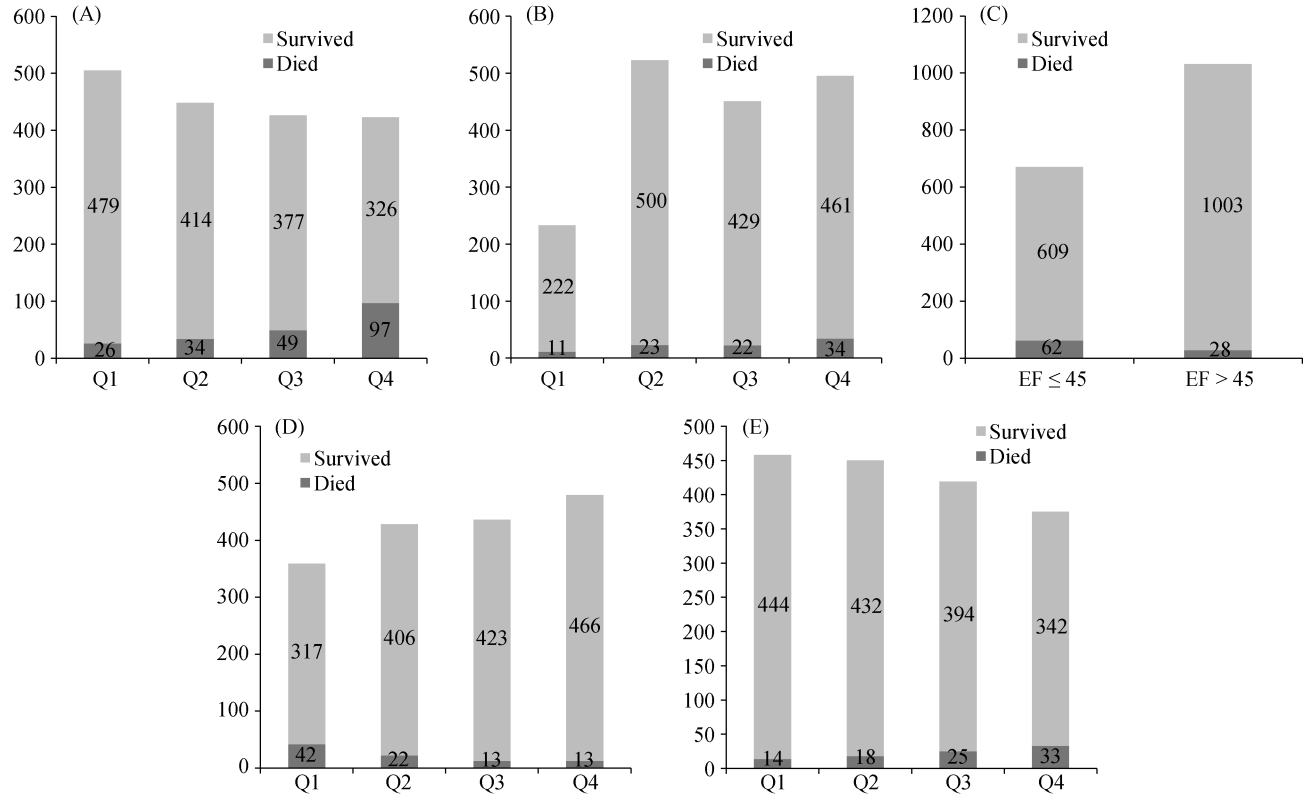

Figure 2. Clinical outcomes of each index in quartile group. (A): clinical outcomes of each HR quartile group; (B): clinical outcomes of each pH value quartile group; (C): clinical outcomes according to EF; (D): clinical outcomes of each eGFR quartile group; (E): clinical outcomes of each NT-pro BNP quartile group. eGFR: epidermal growth factor rate; EF: ejection fraction; NT-pro BNP: N-terminal pro-b-type natriuretic peptide.

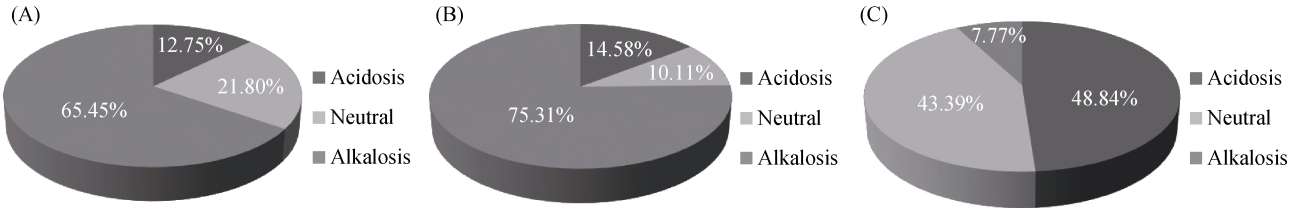

Figure 3. Clinical outcomes according to pH value. (A): the distribution of pH value in all patients; (B): the distribution of pH value in patients Survived during hospital; (C): the distribution of pH value in patients Died during hospital.

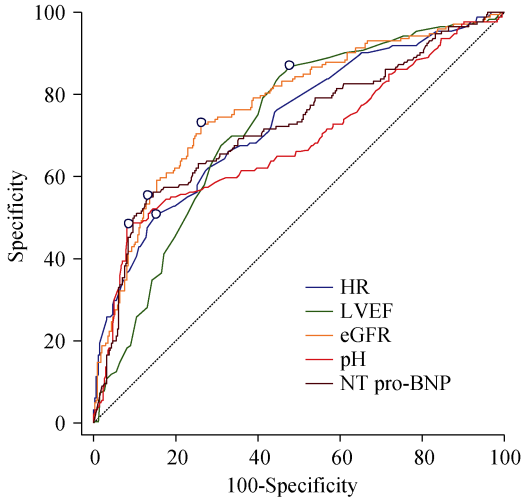

Figure 4. ROC curves for the significant variables. eGFR: estimated glomerular filtration rate; GWTG-HF: get with the guidelines–heart failure; HR: heart rate; LVEF: left ventricular ejection fraction; NT-pro BNP: N-terminal pro-b-type natriuretic peptide; PA: prediction algorithm; ROC: receiver operating characteristic; RPSS: risk prediction score system.

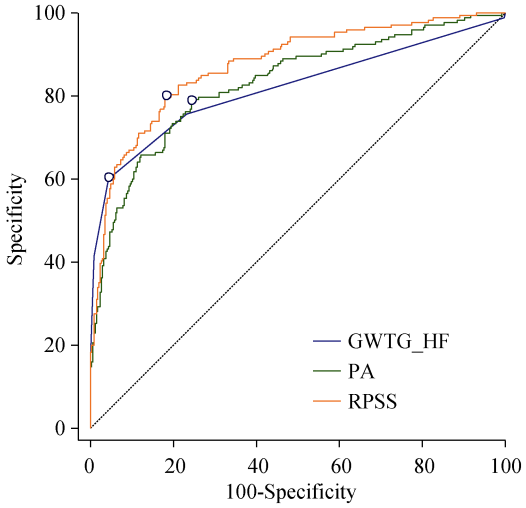

Figure 5. Pairwise comparison of ROC curves for GWTG-HF, PA and PSS. GWTG-HF: get with the guidelines–heart failure; PA: prediction algorithm; ROC: receiver operating characteristic; RPSS: risk prediction score system.

Table 4. Scoring system of the prediction risk model.

Factors	Range	Score
eGFR	≤ 33	3
	33–60	2
	60–90	1
	> 90	0
HR	≤ 75	0
	75–100	1
	> 100	2
LVEF	≤ 45	0
	> 45	1
NT-pro BNP	≤ 200	0
	200–3500	1
	3500–8440	2
	> 8440	3
pH value	≤ 7.362	1
	> 7.362	0

EGFR: estimated glomerular filtration rate; HR: heart rate; LVEF: left ventricular ejection fraction; NT-pro BNP: N-terminal pro-b-type natriuretic peptide.

ROC curve for RPSS is four points. Therefore, clinical doctors should focus special attention on patients with more than four points.

Furthermore, we compared the characteristics of the derivation group and validation group. The baseline characteristics, physiological parameters, management, biochemical test, blood-gas-analysis and echocardiographic results of all subjects are shown in Table 5. There is no significant difference between the two groups. The area under the ROC curve values for the validation RPSS is 0.863 (Figure 6). The cut-off of the ROC curve for the validation group is also four points.

4 Discussion

HF is one of the most burgeoning healthcare problems in the cardiology department. Early prediction and identification of the onset of worsening conditions in high-risk heart failure patients is urgent and necessary for clinical management. Although numerous studies have shown that HF

Table 5. Characters of the derivation group and validation group.

	Derivation group (*n* = 1702)	Validation group (*n* = 729)	*P*-value
Age	73.52 ± 6.57	74.72 ± 5.12	0.842
Male	860 (50.53%)	401 (55.00%)	0.467
Medical history			
Coronary Heart Disease	871 (51.18%)	379 (51.99%)	0.713
Cardiomyopathy	87 (5.11%)	65 (8.92%)	< 0.001
Hypertension	960 (56.04%)	399 (54.73%)	0.447
Pulmonary infection	656 (38.54%)	291 (39.92%)	0.524
Valvular Heart disease	217 (12.75%)	74 (10.15%)	0.071
Pulmonary hypertension	118 (6.93%)	60 (8.23%)	0.261
Diabetes	589 (34.61%)	233 (31.96%)	0.207
Chronic kidney disease	449 (25.50%)	203 (27.86%)	0.455
Arrhythmia	508 (29.85%)	197 (27.02%)	0.160
Hyperlipidemia	212 (12.46%)	87 (11.93%)	0.720
Physical examination			
HR, beats/min	84.00 (73.00–99.00)	82.00 (72.00–94.00)	0.121
RR, breaths/min	18.00 (17.00–20.00)	18.00 (18.00–20.00)	0.874
SBP, mmHg	127.00 ± 28.00	129.50 ± 23.25	0.737
DBP, mmHg	74.00 ± 16.00	77.50 ± 15.00	0.539
BMI, kg/m^2	24.66 ± 7.23	24.60 ± 9.27	0.886
Biochemical			
ALT, U/L	19.50 (11.80–35.80)	17.90 (14.20–33.25)	0.361
AST, U/L	28.50 (16.23–33.69)	26.38 (16.10–34.72)	0.736
γ-GT, U/L	36.70 (22.83–68.38)	32.60 (20.88–74.17)	0.835
Cr, umol/L	103.20 (75.83–145.80)	97.00 (68.90–149.95)	0.800
BUN, mmol/L	7.37 (5.20–15.33)	7.71 (5.67–12.94)	0.373
Uric acid, umol/L	365.65 (294.80–461.84)	353.35 (291.50–475.73)	0.395
TG, mmol/L	1.34 (0.88–2.11)	1.49 (0.99–3.17)	0.218
T-CH, mmol/L	3.86 (3.09–4.04)	3.86 (3.82–5.88)	0.756
HDL, mmol/L	1.00 (0.80–1.28)	1.04 (0.84–1.34)	0.634
LDL, mmol/L	2.31 (1.81–2.85)	2.24 (1.64–2.95)	0.334
CK, U/L	82.50 (41.85–165.25)	77.60 (39.95–153.40)	0.183
c-TnT, ng/L	0.05 (0.02–0.21)	0.05 (0.02–0.19)	0.846
NT-pro BNP, pg/mL	6947.37 (3585.08–19535.10)	5537.39 (2740.15–16904.50)	0.147
Hemoglobin, g/L	120.00 (99.00–146.00)	126.00 (83.00–137.00)	0.751
RBC, 10^{12}/L	4.00 (3.39–4.45)	4.05 (3.36–4.68)	0.647
WBC, 10^9/L	7.27 (5.95–10.28)	7.76 (5.91–9.20)	0.560
PLT, 10^9/L	186.50 (135.25–238.00)	187.00 (137.50–248.00)	0.110
ABG			
pH value	7.36 (7.36–7.43)	7.39 (7.38–7.44)	0.844
PaO_2, mmHg	76.00 (61.40–93.40)	80.21 (61.60–94.28)	0.264
$PaCO_2$, mmHg	35.00 (30.80–40.50)	37.72 (32.03–40.48)	0.273
HCO_3, mmHg	21.96 (18.50–24.10)	22.50 (19.80–24.90)	0.258
SaO_2, %	92.50 (91.10–97.90)	92.70 (92.50–97.40)	0.748
Echocardiographic			
LVDD, mm	54.00 (45.00–57.00)	51.00 (45.00–58.00)	0.601
LVSD, mm	38.00 (31.00–45.00)	38.00 (32.00–47.00)	0.181
LVEF, %	43.00 (35.00–49.00)	44.00 (35.00–52.00)	0.432
FS, %	22.00 (18.00–29.00)	23.00 (20.00–30.00)	0.846

Data were presented as mean ± SD, *n* (%) or median (25th–75th percentiles). ALT: alanine transferase; AST: aspartate aminotransferase; ABG: arterial blood gas; BUN: blood urea nitrogen; BMI: body mass index; CK: creatine kinase; c-TnT: cardiac troponin T; Cr: creatinine; DBP: diastolic blood pressure; FS: fractional shortening; HR: heart rate; HDL: high density lipoprotein; LDL: low density lipoprotein; LVDD: left ventricular diastolic diameter; LVSD: left ventricular systolic dysfunction; LVEF: left ventricular ejection fraction; NT-pro BNP: N-terminal pro-b-type natriuretic peptide; PLT: platelets; PH: potential of hydrogen; PaO_2: partial pressure of O_2; $PaCO_2$: partial pressure of CO_2; RR: respiratory rate; RBC: red blood count; SBP: systolic blood pressure; triglyceride; T-CH: total cholesterol; WBC: white blood count; γ-GT: γ-glutamyl transpeptidase.

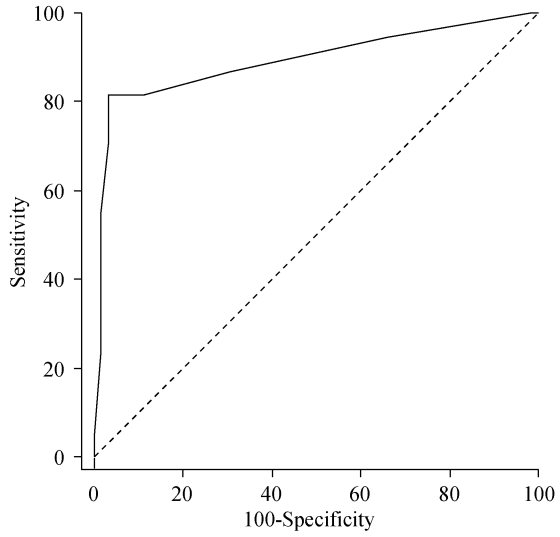

Figure 6. ROC curve of RPSS for validation group. ROC: receiver operating characteristic; RPSS: risk prediction score system.

mortality has steadily declined in America recently,[12–14] HF mortality in China remains at a higher level and has an upward trend. This difference is caused by a variety of reasons, such as medical conditions, social conditions, among others. Several studies have shown that a number of risk factors are related to short-term and long-term mortality after discharge, including age, gender,[15] ventricular function,[16,17] management,[18] and so on.[19] Despite research revealing risk factors for HF mortality, data on HF mortality prediction in elderly patients during admission are limited. The response of several markers such as renal function and natriuretic peptide levels, has consistently failed to predict improvement in outcomes with investigational therapies.[20,21] Although many established algorithms are currently available, these studies have not been validated in Chinese populations. Additionally, arterial blood gas analysis is an important measure for clinical management; however, large sample studies did not include arterial blood gas analysis indicators as candidate factors.[3,9,22,23] Therefore, we combined clinically common factors and an arterial blood gas index to establish another score system that may be more suitable for Chinese patients. Our study showed that the RPSS model had good discriminative capability for in-hospital mortality. In our study, it is shown that several commonly used cardiovascular and non-cardiovascular risk factors may cause rapid development or deterioration of signs and symptoms of heart failure during hospitalization.

Our study showed that the lowest pH quartile was associated with an increased possibility of adverse cardiac events. In HF patients with cardiogenic pulmonary edema, cardiac congestion leads to pulmonary edema with impaired gas exchange and ow cardiac output with a decreased tissue perfusion leads to metabolic acidosis. Lactate is a normal by-product of glucose and amino acid metabolism. Lactic acidosis will be buffered by serum bicarbonate, resulting in metabolic acidosis that is expressed by a low bicarbonate level and low pH value. The poorer the tissue perfusion, the more lactic acid will be produced and the lower the pH value.[24] Thus, the pH value can be used as a comprehensive marker for backward and forward failure, and acid–base balance can be used to assess the general status of heart function in HF patients.[25]

In addition, the left ventricular end diameter and ejection fraction are two commonly used echocardiographic parameters that can provide cardiac function information. Our study showed that the incidence of adverse events during admission in patients with reduced LVEF was higher than that in patients with preserved LVEF. However, another study showed that the outcomes during hospitalization between reduced LVEF patients and preserved LVEF patients were similar.[26] Previous reports have suggested that an ischemic cause is associated with an increased risk of mortality in patients with reduced LVEF, but not in those with preserved LVEF.[27,28] This is mainly caused by the different characteristics of hospitalized patients.

Furthermore, renal dysfunction plays an important role in the progression of HF. Renal dysfunction may aggravate or trigger an episode of HF, as well as contribute to the further progression of HF and poor outcomes.[29–31] Renal dysfunction includes a decreased glomerular filtration rate [assessed using different glomerular filtration rate (GFR) formulas based on the measurement of circulating creatinine and cystatin C],abnormal tubular function [as reflected by high levels of neutrophil gelatinase-associated lipocalin (NGAL), kidney injury molecule1 (KIM1) in both peripheral blood and urine] and inadequate endocrine activity [as reflected by inadequate secretion of erythropoietin (EPO)].[32] It is suggested that renal-dysfunction may be the result of generalized neurohormonal activation, inflammation, oxidative stress, impaired intra-renal hemodynamics as a consequence of either abnormal extra-renal hemodynamics affecting renal blood flow and pressures or deranged intra-renal hemodynamic regulatory mechanisms, intrinsic renal disease (e.g., diabetes, hypertension), and iatrogenic causes (e.g. high-dose loop diuretic therapy).[30,33,34] creatinine (Cr) and BUN are the most commonly used markers of renal function in the clinical setting. They are not only markers of renal dysfunction and hypoperfusion but may also reflect neurohormonal activation in HF.[35] In our study, the areas under the Cr, BUN and eGFR curves were 0.779, 0.757 and

0.773, respectively. These results prove that renal function is related to adverse cardiac events in HF patients. This is consistent with the findings of two famous registries that demonstrated that renal function at admission is among the best discriminators between hospital survivors and non-survivors.[3,23]

Our findings demonstrated that HR; LVEF, as determined from echocardiography; pH value; eGFR; and NT-pro BNP should be considered when assessing the risk of in-hospital mortality after admission for patients with AHF. Our risk prediction model, RPSS, has important significance for precision risk stratification of in-hospital patients with AHF and could provide better prediction for in-hospital mortality.

These findings should be considered in the context of several limitations. This study is a single-center, retrospective control study and the population was rather small. Therefore, cross-validation or bootstrap resampling would be a better procedure for grouping and analysis. Large sample size studies in the future could adopt these methods. Additionally, this model reports in-hospital mortality only and was not validated for post-discharge outcomes. Other factors might be of prognostic value for post-discharge mortality or re-hospitalization. The mortality risk factors might have been influenced by other factors that were included in the database or that were considered to be candidate variables. Thus, linear terms might be not appropriate for predictors with non-linear associations; restricted cubic splines or fractional polynomials might be better choices.

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