Development and validation of a nomogram for predicting intensive care unit mortality in patients with acute pancreatitis: a dual-center retrospective cohort study

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Abstract

Introduction: Acute pancreatitis (AP) is a severe inflammatory disease causing abdominal pain and organ failure, potentially leading to necrosis and organ dysfunction. This study aimed to create a nomogram to predict mortality in intensive care unit (ICU) patients with AP.

Material and methods: We conducted a cohort study using the Medical Information Mart for Intensive Care IV (MIMIC-IV) and data from the First People's Hospital of Changde City, selecting variables via univariate logistic regression and constructing a nomogram with multivariate logistic regression. The nomogram's performance was evaluated using the area under the curve (AUC) calculated from the receiver operating characteristic curve (ROC), reclassification improvement (NRI) and integrated discrimination improvement (IDI), while clinical utility was assessed with a calibration curve and decision curve analysis (DCA) validated the predictive model's efficacy.

Results: A total of 1100 patients were analyzed, with ICU mortality rates of 7.9% in the training set, 9.2% in the internal validation set, and 13.3% in the external validation set. From the 32 extracted variables, five were ultimately selected: hemoglobin, urea nitrogen, SAPS II score, OASIS score, and myocardial infarction. We subsequently developed and validated a nomogram. The AUC, NRI, and IDI of the nomogram were superior to those of the traditional SAPS II and OASIS scoring systems. Calibration curves and the Hosmer-Lemeshow test revealed satisfactory alignment between predicted and observed outcomes, while DCA substantiated the clinical utility of the model across a wide range of threshold probabilities.

Conclusions: The nomogram showed good performance in predicting mortality among ICU patients with AP and may serve as a valuable tool for clinicians to identify high-risk patients and optimize medical decision-making.

Key words: intensive care unit mortality, nomogram, acute pancreatitis, Medical Information Mart for Intensive Care IV.

Introduction

Acute pancreatitis (AP) is one of the most frequent gastrointestinal diseases, with its incidence showing an increasing trend year by year [1–3]. Severe acute pancreatitis (SAP) accounts for approximately 20%

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of AP cases and is characterized by necrosis of the pancreatic or peripancreatic tissue [4]. In contrast to the more favorable clinical outcomes observed in patients with mild AP, SAP is still associated with a worse prognosis, featuring a substantial mortality rate of 20–40% [5]. This significantly influences the health and quality of life of people around the world [6].

Although the overall mortality rate for AP has decreased owing to enhanced critical care and accurate, timely diagnosis, the severity of mortality and long-term complications persists [7, 8]. Accurate and timely assessment of the condition and prognosis of AP patients holds significant importance for clinicians [9]. This facilitates risk stratification of patients and enables the provision of individualized treatment, ultimately contributing to a reduction in mortality risk.

In recent years, the prognosis of AP has been evaluated using various scoring systems, including the Acute Physiology and Chronic Health Evaluation Scoring System II (APACHE II), BISAP scores, as well as biochemical markers such as the glucose-to-lymphocyte ratio and the estimated glomerular filtration rate (eGFR) [10–12]. However, no evidence-based practice guidelines are available, and the prognostic precision of an individual laboratory biomarker or score system may be susceptible to fluctuations in its accuracy. Currently, there is no efficient and simple prognostic scoring tool to estimate the survival outcomes of AP patients in the intensive care unit (ICU).

Identifying patients with AP at high risk of mortality during their initial admission to the ICU can significantly aid clinicians in achieving timely diagnosis and devising tailored therapeutic strategies. Reviewing the recently published literature, the OASIS score, SAPS II score, elevated blood urea nitrogen (BUN), and malnutrition are significantly associated with an increased risk of mortality related to AP [13–16]. However, few predictive models for ICU mortality in AP incorporate these simple yet effective factors.

Owing to the limitations of current predictive models, developing a predictive model for ICU mortality in AP patients that leverages routine clinical and laboratory data is essential to ensure its ready implementation in clinical practice. It has been verified that nomograms are effective in providing evidence-based and personalized risk estimates, which play a crucial role in optimizing clinical management and assessing patient outcomes. Utilizing demographic characteristics, clinical variables, and laboratory parameter derived from the Medical Information Mart for Intensive Care IV (MIMIC-IV) database and an external validation cohort, our objective was to develop a nomogram model for predicting ICU mortality in patients with AP.

Material and methods

Source of data

To develop and validate a prediction model, this dual-center retrospective study was conducted involving patients with AP. Internal cohorts were derived from the MIMIC-IV database; eligible patients were randomly allocated in a 7 : 3 ratio to the training and internal-validation sets, respectively. For external validation, an independent dataset was compiled from the First People's Hospital of Changde City, encompassing patients who met identical inclusion and exclusion criteria and were admitted between February 2020 and February 2023.

The MIMIC-IV database is a dataset that includes comprehensive health-related information from nearly 60,000 patients who were treated in the ICU at the Beth Israel Deaconess Medical Center in the United States. Comprehensive patient data, encompassing demographic characteristics, vital signs, laboratory results, imaging reports, organ failure assessments, illness severity scores, comorbid conditions, diagnoses, therapeutic interventions, hospital length of stay, and survival outcomes, were documented between 2008 and 2019. We have successfully accomplished an online course offered by the National Institutes of Health (NIH), which has enabled us to gain access to the MIMIC-IV database (certification number: No. 64566867).

Study population

Utilizing Structured Query Language (SQL) in conjunction with PostgreSQL (version 9.6, University of California, Berkeley), data extraction was performed to retrieve pertinent information linked to each patient's distinct HADM_ID from the MIMIC-IV database. A total of 1345 patients hospitalized in the ICU with AP were identified from the MIMIC-IV database using the International Classification of Diseases, 9th Edition (ICD-9) code 5770 and 10th Edition (ICD-10) code K85. The external validation cohort included patients with AP who were initially admitted to the Hepatobiliary Surgery Department and subsequently transferred to the ICU due to changes in their condition. The exclusion criteria were as follows: (i) patients with missing data > 25% or outcome variable missing; (ii) ICU stay < 24 h and > 90 days; (iii) non-first ICU admission.

Clinical variables and definition

During the first day of ICU admission, 32 variables encompassing clinical (age, sex), laboratory (hemoglobin, anion gap, calcium, chloride, creatinine, glucose, potassium, white blood cell [WBC],

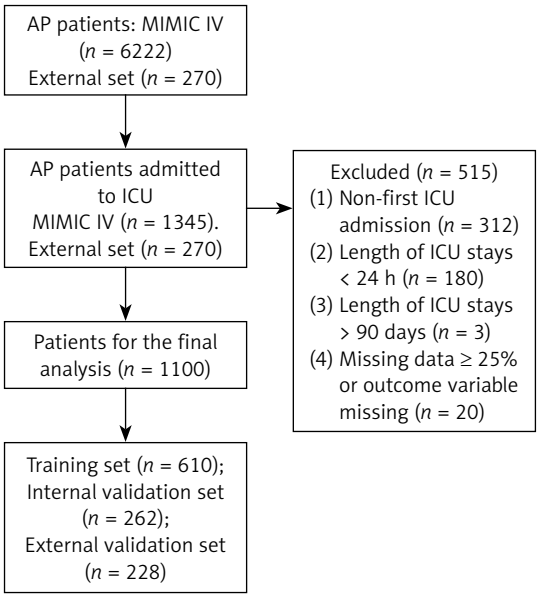

Figure 1. Flow chart of the study population

hematocrit, total bilirubin, platelets, alanine aminotransferase [ALT], aspartate aminotransferase [AST]), comorbidity (myocardial infarct, congestive heart failure [CHF], renal disease, severe liver disease, rheumatic disease, diabetes, chronic obstructive pulmonary disease [COPD], malignant cancer), scoring systems (Simplified Acute Physiology Score II [SAPS II], Sequential Organ Failure Assessment [SOFA] score, Oxford Acute Severity of Illness Score [OASIS], systemic inflammatory response syndrome [SIRS], Glasgow Coma Scale [GCS], ICU stay, treatments (mechanical ventilation [MV], renal replacement therapy [RRT]), and outcome data were collected. The outcome was mortality during the ICU admission. To address missing data, two methods were employed: (1) variables with > 25% missing values were excluded; (2) the missing data for the remaining variables was imputed using either the mean or the median.

Risk nomogram development and evaluation

A random selection process was used to assign 70% of the participants from the MIMIC-IV dataset to the training set, while the remaining 30% were assigned to the internal validation set. The training set was employed for the construction of a nomogram, whereas the internal validation set was used for conducting internal validation. Additionally, an external dataset was used for testing (external validation). Univariate logistic regression analysis that integrated various characteristics and clinical outcomes in the training cohort was applied to variables selection. Employing a multivariable logistic regression algorithm, the risk score was developed based on the selected significant variables ($p < 0.05$). These variables were further employed to develop a nomogram for assessing the risk of ICU mortality. The nomogram's performance was evaluated based on the AUC, calibration, and decision and clinical impact curves with 95% confidence intervals (CI).

Statistical analysis

All statistical analyses were performed using STATA version 15.0 (Stata Corporation, College Station, Texas, USA) and R software version 4.2.1 (The R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics encompassed both continuous and categorical variables. Continuous variables are expressed as means ± standard deviations (SDs) or medians with interquartile ranges. Categorical variables are presented as frequencies and percentages. For the comparison of continuous variables, Student's *t*-test or Wilcoxon signed-rank test was employed, whereas categorical variables were analyzed using the χ^2 test or Fisher's exact test. A two-tailed *p*-value less than 0.05 was considered statistically significant.

Results

Patient characteristics

Based on ICD-9 and ICD-10 codes, we identified 6222 patients with AP in the MIMIC-IV database. Among these, 1345 patients were admitted to the ICU. An additional cohort of 270 AP patients was retrospectively enrolled from the The First People's Hospital of Changde City. After excluding 515 participants who did not meet the inclusion criteria, a total of 1,100 eligible AP patients were finally included. The MIMIC-IV dataset was randomly divided into two parts: 70% of the data ($n = 610$) was used for model training, and 30% of the data ($n = 262$) was used for internal validation. The external validation set finally consisted of 228 patients. Figure 1 describes the criteria and procedures for the inclusion and exclusion of the study population. The demographic and clinical data of the included patients are summarized in Table I. ICU mortality was 7.9% in the training set, 9.2% in the internal validation set, and 13.3% in the external validation set.

Variables selection

Univariate analysis showed that age, myocardial infarction, severe liver disease, SAPS II score, OASIS score, SOFA score, SIRS score, ICU stay, WBC, urea nitrogen, creatinine, MV, RRT, hemoglobin, anion gap, and GCS score were associated with ICU mortality (Table II). After the multivariate logistic regression analyses, 5 variables were

Table I. Baseline demographic and clinical characteristics of patients with acute pancreatitis

Variables	Training cohort (*n* = 610)	Internal validation cohort (*n* = 262)	External validation cohort (*n* = 228)
Sex			
Female	262 (43.0%)	108 (41.2%)	98 (43.0%)
Male	348 (57.0%)	154 (58.8%)	130 (57.0%)
Age			
≤ 60	310 (50.8%)	151 (57.6%)	120 (52.6%)
> 60	300 (49.2%)	111 (42.4%)	108 (47.4%)
Myocardial infarction			
No	544 (89.2%)	238 (90.8%)	205 (89.9%)
Yes	66 (10.8%)	24 (9.2%)	23 (10.1%)
CHF			
No	487 (79.8%)	215 (82.1%)	178 (78.1%)
Yes	123 (20.2%)	47 (17.9%)	50 (21.9%)
Renal disease			
No	493 (80.8%)	220 (84.0%)	171 (75.0%)
Yes	117 (19.2%)	42 (16.0%)	57 (25.0%)
Severe liver disease			
No	553 (90.7%)	231 (88.2%)	194 (85.1%)
Yes	57 (9.3%)	31 (11.8%)	34 (14.9%)
Rheumatic disease			
No	586 (96.07%)	252 (96.18%)	217(95.1%)
Yes	24 (3.93%)	10 (3.82%)	11(4.9%)
Diabetes			
No	439 (71.97%)	186 (70.99%)	153 (67.1%)
Yes	171 (28.03%)	76 (29.01%)	75 (32.9%)
COPD			
No	478 (78.36%)	208 (79.39%)	186 (81.8%)
Yes	132 (21.64%)	54 (20.61%)	42 (18.2%)
Malignant cancer			
No	566 (92.79%)	236 (90.08%)	212 (93.0%)
Yes	44 (7.21%)	26 (9.92%)	16 (7.0%)
GCS			
3–8	119 (19.5%)	41 (15.6%)	50 (22.0%)
9–12	101 (16.6%)	38 (14.5%)	40 (17.5%)
13–15	390 (63.9%)	183 (69.8%)	138 (60.5%)
SOFA			
≤ 10.5	475 (77.9%)	211 (80.5%)	106 (46.5%)
> 10.5	135 (22.1%)	51 (19.5%)	122 (53.5%)
SAPS II			
≤ 48.5	473 (77.5%)	205 (78.2%)	184 (80.7%)
> 48.5	137 (22.5%)	57 (21.8%)	44 (19.3%)
OASIS			
≤ 44.5	501 (82.1%)	208 (79.4%)	183 (80.3%)
≥ 44.5	109 (17.9%)	54 (20.6%)	45 (19.7%)
SIRS	3.0 [2.0; 4.0]	3.0 [3.0; 4.0]	3.0 [2.0; 4.0]

Table I. Cont.

Variables	Training cohort (*n* = 610)	Internal validation cohort (*n* = 262)	External validation cohort (*n* = 228)
Urea nitrogen [mg/dl]			
≤ 26	368 (60.3%)	174 (66.4%)	110 (48.3%)
> 26	242 (39.7%)	88 (33.6%)	118 (51.7%)
MV			
No	391 (64.1%)	168 (64.1%)	134 (58.8%)
Yes	219 (35.9%)	94 (35.9%)	94 (41.2%)
RRT			
No	568 (93.1%)	242 (92.4%)	208 (91.2%)
Yes	42 (6.9%)	20 (7.6%)	20 (8.8%)
Hemoglobin [g/dl]			
≤ 8.6	78 (12.8%)	43 (16.4%)	68 (29.8%)
> 8.6	532 (87.2%)	219 (83.6%)	160 (70.2%)
Anion gap [mmol/l]			
≤ 16	338 (55.4%)	140 (53.4%)	108 (47.4%)
> 16	272 (44.6%)	122 (46.6%)	120 (52.6%)
ALT [U/l]			
≤ 40	238 (39.0%)	100 (38.2%)	91 (39.9%)
> 40	372 (61.0%)	162 (61.8%)	137 (60.1%)
AST [U/l]			
≤ 35	146 (23.9%)	64 (24.4%)	52 (22.8%)
> 35	464 (76.1%)	198 (75.6%)	176 (77.2%)
Calcium [mg/dl]	8.1 [7.4; 8.6]	8.1 [7.4; 8.7]	8.0 [7.3; 8.6]
Chloride [mmol/l]	104.0 [98.0; 108.0]	103.5 [99.0; 108.0]	103.0 [99.0; 107.0]
Creatinine [mg/dl]	1.1 [0.8; 2.0]	1.0 [0.7; 1.8]	1.5 [0.8; 2.7]
Glucose [mg/dl]	129.0 [104.0; 183.8]	126.5 [105.0; 179.8]	133.0 [107.0; 190.5]
Potassium [mmol/l]	4.1 [3.7; 4.6]	4.1 [3.7; 4.6]	4.2 [3.8; 4.6]
WBC [K/µl]	12.9 [9.0; 18.4]	12.1 [8.5; 17.2]	12.4 [8.6; 19.0]
Hematocrit [g/dl]	35.0 [25.3; 38.1]	34.9 [27.2; 39.5]	32.6 [26.2; 39.1]
Total bilirubin [mg/dl]	1.0 [0.6; 2.5]	1.0 [0.5; 2.6]	1.6 [0.6; 3.6]
Platelets [K/µl]	196.0 [138.0; 278.0]	208.5 [146.5; 298.8]	187.0 [126.8; 272.5]
ICU stay [days]	2.80 [1.34; 6.30]	2.55 [1.33; 7.22]	3.1 [1.6; 8.6]
ICU mortality (%)			
No	562 (92.1%)	238 (90.8%)	198 (86.7%)
Yes	48 (7.9%)	24 (9.2%)	30 (13.3%)

ICU – intensive care unit, SAPS II – Simplified Acute Physiology Score II, OASIS – Oxford Acute Severity of Illness Score, SIRS – systemic inflammatory response syndrome, SOFA – Sequential Organ Failure Assessment, MV – mechanical ventilation, RRT – renal replacement therapy, WBC – white blood cell, ALT – aspartate aminotransferase, AST – alanine aminotransferase, COPD – chronic pulmonary disease, CHF – congestive heart failure, GCS – Glasgow Coma Scale.

found to be predictors of ICU mortality (Table III): hemoglobin, urea nitrogen, SAPS II score, OASIS score, and myocardial infarction.

Construction and validation of the nomogram

Based on the findings of multivariate logistic regression, we constructed a nomogram to predict mortality in ICU patients with AP. The specific values of hemoglobin, urea nitrogen, SAPS II score, OASIS score, and myocardial infarction can be applied to determine the corresponding points on the nomogram. By summing the points derived from each variable, the nomogram calculates the predicted risk of ICU mortality in patients with AP (Figure 2).

Table II. Univariate logistic regression analysis of risk factors associated with ICU mortality in patients with acute pancreatitis

Variables	Subgroup	Univariate analysis		
		OR	95% CI	*P*-value
Age	≤ 60	1		0.006
	> 60	2.328	1.273–4.260	
Myocardial infarction	No	1		0.002
	Yes	3.010	1.489–6.085	
Severe liver disease	No	1		0.010
	Yes	2.586	1.257–5.318	
Urea nitrogen [mg/dl]	≤ 26	1		< 0.001
	> 26	5.787	3.014–11.113	
Hemoglobin [g/dl]	≤ 8.6	1		0.029
	> 8.6	0.463	0.232–0.925	
Anion gap [mmol/l]	≤ 16	1		0.002
	> 16	2.671	1.447–4.931	
MV	No	1		< 0.001
	Yes	3.412	1.901–6.124	
RRT	No	1		0.001
	Yes	3.665	1.702–7.894	
GCS	≥ 13 and ≤ 15	1		< 0.001
	≥ 9 and ≤ 12	2.432	1.069–5.536	
	≥ 3 and ≤ 8	5.399	2.824–10.321	
SAPS II	≤ 48.5	1		< 0.001
	> 48.5	19.550	9.679–39.489	
OASIS	≤ 44.5	1		< 0.001
	> 44.5	16.239	8.416–31.334	
SOFA	≤ 10.5	1		< 0.001
	> 10.5	14.765	7.585–28.738	
SIRS		1.606	1.106–2.330	0.013
ICU stay [days]		3.540	1.980–6.330	< 0.001
WBC [K/µl]		1.038	1.007–1.069	0.015
Creatinine [mg/dl]		1.178	1.037–1.324	0.007

ICU – intensive care unit, SAPS II – Simplified Acute Physiology Score II, OASIS – Oxford Acute Severity of Illness Score, SIRS – systemic inflammatory response syndrome, SOFA – Sequential Organ Failure Assessment, MV – mechanical ventilation, RRT – renal replacement therapy, WBC – white blood cells, GCS – Glasgow Coma Scale, OR – odds ratio, CI – confidence interval.

Table III. Selected variables by multivariate logistic regression analysis

Variable	Subgroup	Multivariate analysis		
		OR	95% CI	*P*-value
Hemoglobin [g/dl]	≤ 8.6	1		0.045
	> 8.6	0.414	0.175–0.982	
Urea nitrogen [mg/dl]	≤ 26	1		0.017
	> 26	2.508	1.182–5.323	
SAPS II	≤ 48.5	1		< 0.001
	> 48.5	5.440	2.267–13.052	
OASIS	≤ 44.5	1		< 0.001
	> 44.5	5.346	2.330–12.267	
Myocardial infarction	No	1		0.046
	Yes	2.352	1.015–5.453	

SAPS II – Simplified Acute Physiology Score II, OASIS – Oxford Acute Severity of Illness Score, OR – odds ratio, CI – confidence interval.

Model evaluation and clinical use

In this study, we conducted a comparative analysis of the predictive capabilities of our nomogram and SAPS II score and OASIS score for ICU mortality among patients with AP.

The results indicated that AUC was 0.882 (95% CI: 0.830–0.924) for the training set, 0.920 (95% CI: 0.873–0.951) for the internal validation set, and 0.847 (95% CI: 0.753–0.915) for the external validation set, both of which outperformed the SAPS II and OASIS score (Figure 3).

NRI values for the nomogram compared to the SAPS II score were 0.154 (95% CI: 0.054-0.254), 0.233 (95% CI: 0.024–0.441) and 0.112 (95% CI:

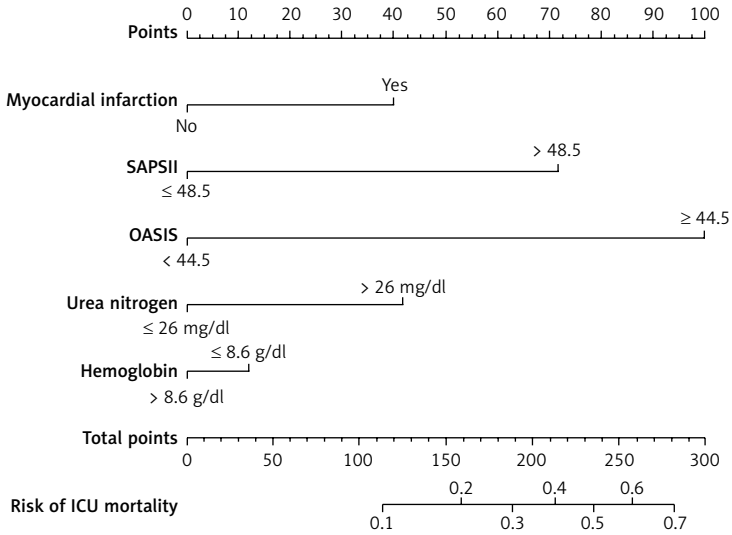

Figure 2. The nomogram used for predicting ICU mortality in intensive care patients with acute pancreatitis

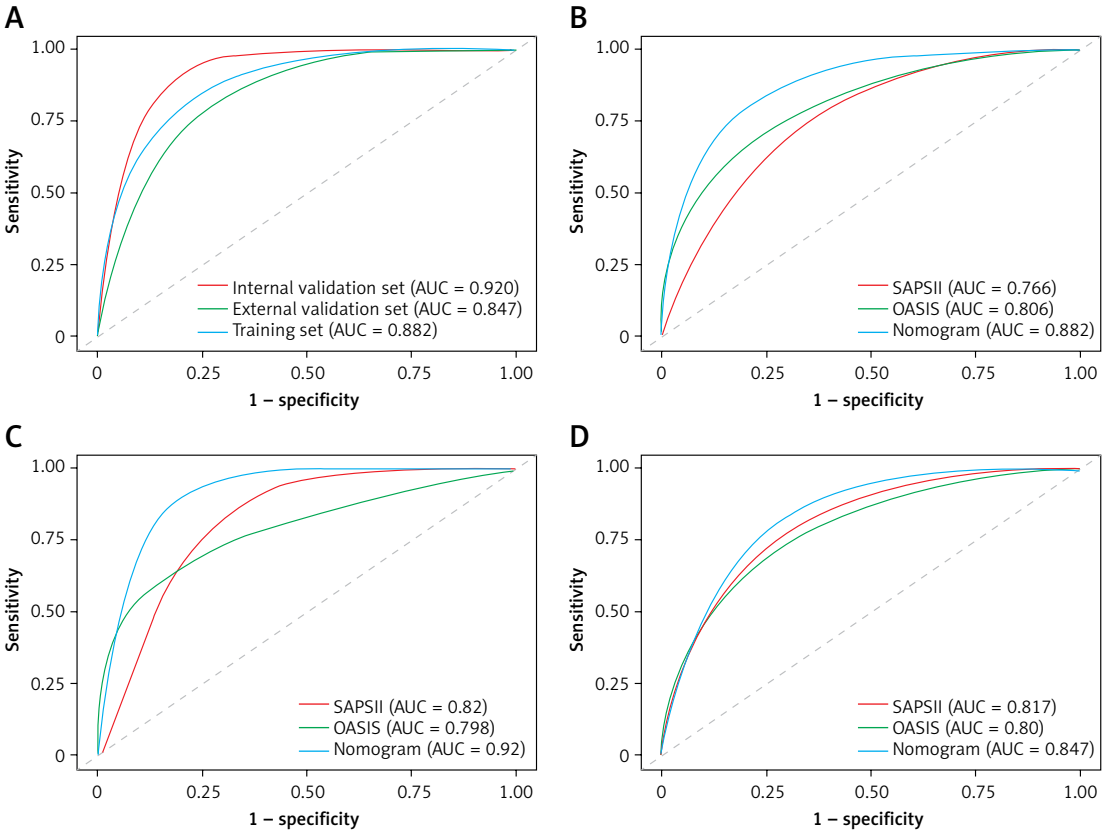

Figure 3. The AUC of the nomogram and comparisons of risk prediction performance (the nomogram, SAPS II, and OASIS). **A** – The AUC of the nomogram in training, internal validation, and external validation sets, respectively. **B** – Comparisons of risk prediction performance in training dataset. **C** – Comparisons of risk prediction performance in internal validation set. **D** – Comparisons of risk prediction performance in external validation set

Table IV. Predictive performances and validation of the nomogram

Predictive model	AUC	*P*-value	NRI	*P*-value	IDI	*P*-value
Training set						
Nomogram	0.882 (0.830–0.924)					
SAPS II	0.766 (0.699–0.835)	< 0.001	0.154 (0.054–0.254)	< 0.001	0.102 (0.063–0.141)	< 0.001
OASIS	0.806 (0.736–0.872)	0.001	0.154 (0.054–0.254)	0.003	0.066 (0.031–0.102)	< 0.001
Internal validation set						
Nomogram	0.920 (0.873–0.951)					
SAPS II	0.820 (0.758–0.872)	0.036	0.233 (0.024–0.441)	0.029	0.051 (0.017–0.104)	0.045
OASIS	0.798 (0.688–0.893)	< 0.001	0.160 (0.010–0.311)	0.037	0.112 (0.056–0.168)	< 0.001
External validation set						
Nomogram	0.847(0.753–0.915)					
SAPS II	0.817 (0.719–0.899)	0.002	0.112 (0.022–0.202)	0.015	0.061 (0.032–0.090)	< 0.001
OASIS	0.800 (0.687–0.888)	0.008	0.291 (0.257–0.425)	< 0.001	0.050 (0.012–0.112)	0.043

AUC – area under the curve, NRI – net reclassification improvement, IDI – integrated discrimination Improvement, SAPS II – Simplified Acute Physiology Score II, OASIS – Oxford Acute Severity of Illness Score.

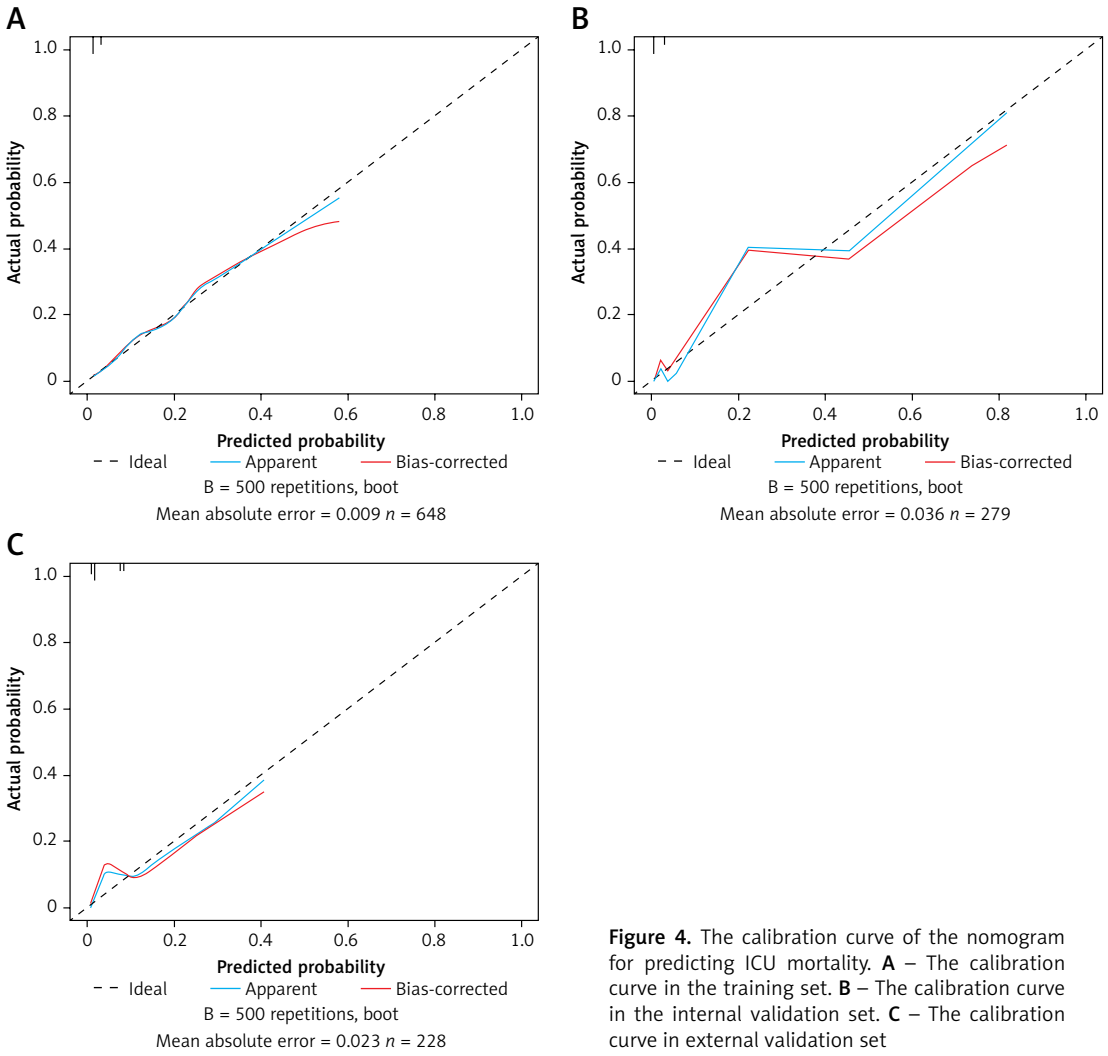

Figure 4. The calibration curve of the nomogram for predicting ICU mortality. **A** – The calibration curve in the training set. **B** – The calibration curve in the internal validation set. **C** – The calibration curve in external validation set

0.022–0.202) in the training, internal validation, and external validation sets, respectively; the corresponding IDI values were 0.102 (95% CI: 0.063–0.141), $p < 0.001$, 0.051 (95% CI: 0.017–0.104), $p = 0.045$, and 0.061 (95% CI: 0.032–0.090), $p < 0.001$, respectively (Table IV). Analysis comparing the nomogram with OASIS score revealed trends similar to those observed for the SAPS II score (Table IV). These findings suggest that the nomogram has better discriminative ability and outperforms the SAPS-II and OASIS score.

The calibration curve exhibited a satisfactory alignment during internal and external validation (Figure 4). The Hosmer-Lemeshow test demonstrated that our predicted values were close to the observed values for the training set ($p = 0.793$), for the internal validation set ($p = 0.082$), and for the external validation set ($p = 0.179$), which suggests that the model accurately predicted the risk of ICU mortality in AP patients. DCA analysis revealed that the nomogram offers a superior net benefit for predicting ICU mortality when compared to the "treat all or none" strategy, spanning a wide range of threshold probabilities. Furthermore, the nomogram showed a superior standardized net benefit over SAPS II score and OASIS score regarding patient outcomes (Figure 5).

Discussion

We developed and validated a risk model for the early prediction of ICU mortality for patients with AP based on the MIMIC-IV database and an external validation set. The included variables were typically measured during the crucial first 24 h after admission. We adhered to the TRIPOD statement's recommendation to use the bootstrapping method for calculating AUCs and calibration curves [17]. The performance of the nomogram was acceptable and robust based on the AUCs, NRI, and IDI obtained from the training and internal validation sets. Additionally, the calibration tests and DCA results derived from the training and internal validation sets suggest an acceptable overall fit and potential clinical utility. The model's performance was successfully confirmed in the external validation set. This nomogram integrates 5 distinct prognostic factors (hemoglobin, urea nitrogen, SAPS II score, OASIS score, and myocardial infarction), which are closely related to clinical practice and hold potential clinical reference value. These selected clinical variables are easily accessible and do not require elaborate diagnostic procedures, sophisticated imaging modalities, or invasive maneuvers. It may serve as

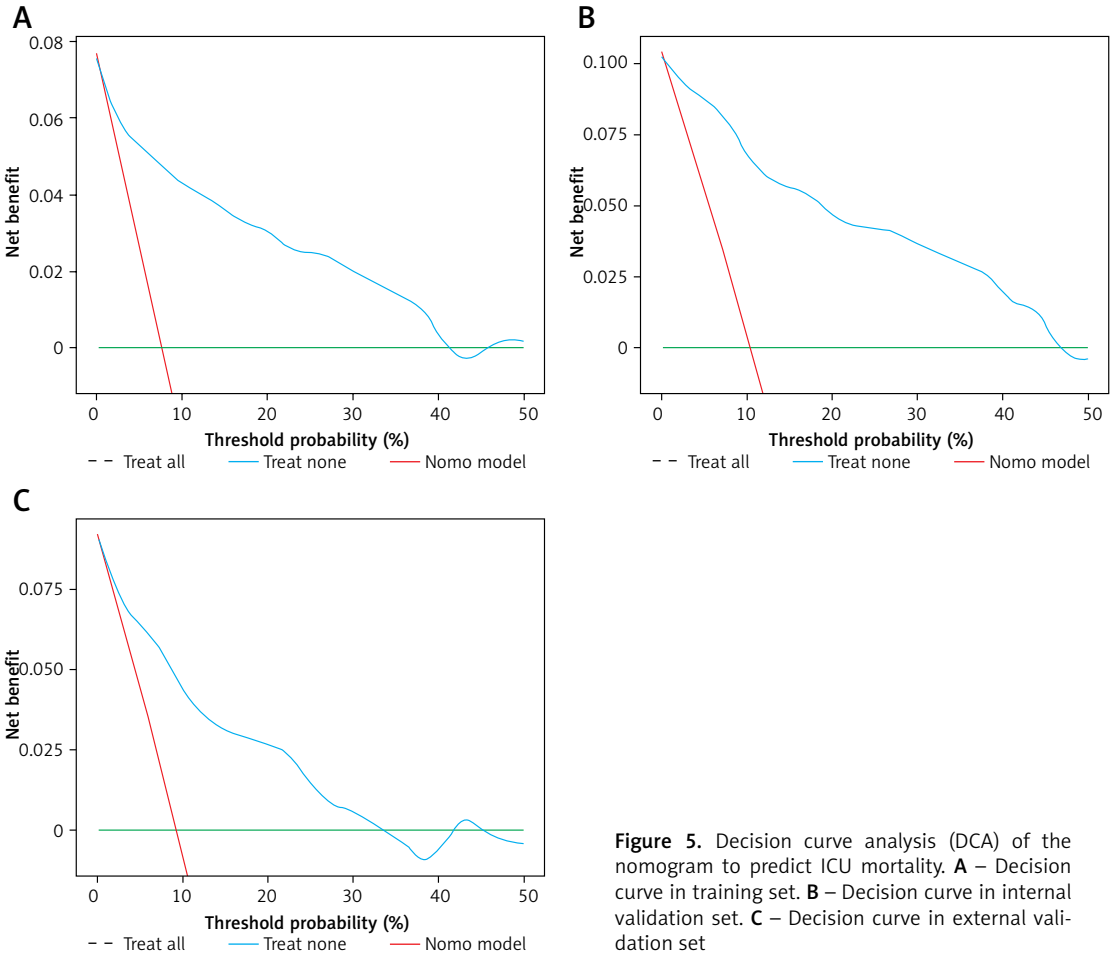

Figure 5. Decision curve analysis (DCA) of the nomogram to predict ICU mortality. **A** – Decision curve in training set. **B** – Decision curve in internal validation set. **C** – Decision curve in external validation set

a potentially useful tool for clinicians and investigators to assess high-risk patients and estimate the severity of AP.

Our research incorporated two scoring systems, the SAPS II and OASIS scores, to predict ICU mortality, resulting in a more comprehensive prediction than using either the SAPS II or OASIS score individually. Consistent with our findings, previous studies [18, 19] indicated that the SAPS II and OASIS scores are effective predictors of prognosis for ICU-admitted patients with AP. Additional research has also confirmed that SAPS II and OASIS are reliable tools for predicting outcomes in various patient groups [20, 21]. The SAPS II scoring system assesses various physiological metrics, including heart rate, blood pressure, body temperature, respiratory frequency, and laboratory test outcomes, thereby delivering a comprehensive evaluation of a patient's physiological status and the severity of their illness [22]. In AP, the development of organ dysfunction greatly affects prognosis [23]. The SAPS II score effectively captures these critical changes, offering valuable prognostic information [24]. In contrast, the OASIS score focuses on clinical signs and lab results, making it especially relevant for patients in critical care [25]. A notable characteristic of the OASIS score is its emphasis on evaluating the severity of acute illness, which has demonstrated predictive ability, especially in scenarios involving infections and multiple organ failure [26].

Moreover, our data also revealed that urea nitrogen (OR = 2.508; 95% CI: 1.182–5.323) is an independent predictor of increased ICU mortality risk in patients with AP. This result aligns with previous studies that found elevated urea nitrogen levels are a reliable indicator for predicting mortality and severity in AP [27, 28]. Research by Khan *et al.* showed that patients with AP have higher mortality rates due to myocardial infarction [29]. Additionally, a large sample study also indicates that the development of myocardial infarction is linked to increased morbidity and mortality [30]. Our model also indicated that myocardial infarction (OR = 2.352; 95% CI: 1.015–5.453) is a significant predictor of ICU mortality, consistent with findings from previous studies.

In our analysis, the majority of factors exhibited a positive correlation with the risk of ICU mortality; conversely, hemoglobin levels demonstrated a negative association (OR = 0.414; 95% CI: 0.175–0.982). Anemia emerged as a crucial and sensitive marker indicative of nutritional inadequacies, with severe cases of anemia correlating with unfavorable outcomes in patients with SAP [31]. Prior research has similarly indicated that reduced hemoglobin levels are linked to an increased risk of mortality [32]. These findings are consistent with our results. Severe anemia may increase mortality through several pathways: nutritional deficiencies that heighten infection risk, inflammatory processes that hinder erythropoiesis, and bacterial endotoxins that can cause blood loss. Together, these factors reduce oxygen delivery to vital organs, leading to tissue hypoxia and ultimately contributing to multi-organ dysfunction [33].

Certain limitations of this study necessitate careful consideration. First, this research is a retrospective analysis utilizing data from the MIMIC-IV database, along with a small external validation set for further validation. Additional large-scale, multicenter prospective studies are essential to further evaluate the performance of the nomogram. Second, variables such as albumin and fibrinogen with missing values > 25% were excluded from the analysis. Third, our study included only ICU-admitted patients with AP, which may result in selection bias. Fourth, owing to inherent limitations of the database, we were unable to perform a detailed analysis of the underlying etiologies of acute pancreatitis or to reliably determine the interval between symptom onset and ICU admission. Finally, without dynamic parameters, we cannot assess the mortality risk for ICU patients with AP in real-time.

In conclusion, we developed and validated a nomogram to predict mortality in ICU patients with AP using 5 key variables assessed within the first 24 h of admission. The nomogram may help clinicians identify AP patients at high risk of mortality, potentially supporting timely interventions and improving medical resource allocation. Further validation of this nomogram with a more diverse dataset is crucial to establish its generalizability and potential clinical value.

Data availability

The MIMIC-IV dataset was publicly shared. Investigators can obtain access by completing an online course known as Protecting Human Research Participants. The preprocessed version of the external validation set used in this study can be obtained by contacting the corresponding author.

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Institutional review board statement

Given the retrospective nature of this study, informed consent was waived by the ethics community and all analyses were performed in accor-

dance with the Declaration of Helsinki and the ethical guidelines for clinical studies of The First People's Hospital of Changde City.

Ethical approval

The authors are responsible for all aspects of this study, ensuring that any issues related to accuracy or integrity of the investigation are thoroughly examined and satisfactorily resolved. Importantly, the MIMIC IV database has obtained ethical clearance from the Institutional Review Boards (IRBs) at BIDMC and MIT. Additionally, since the database does not include confidential health information, a waiver of the informed consent requirement was granted as part of the IRB's approval procedure.

Conflict of interest

The authors declare no conflict of interest.

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