Clinical Medicine Research
2025, Vol. 14, No. 5, pp. 169-180
https://doi.org/10.11648/j.cmr.20251405.12

Research Article

Construction of a Nomogram for Predicting ICU Mortality Risk in Patients with Spinal Fractures Based on the APACHE IV

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Abstract

This study aimed to develop and validate a nomogram for predicting ICU mortality risk in patients with spinal fractures to improve prognostic accuracy. Using data from 1,146 patients in the eICU Collaborative Research Database, independent risk factors—including age, BMI, APACHE IV score, admission source, mechanical ventilation, spinal cord injury, sepsis, oxygen saturation, white blood cell count, hemoglobin, and glucose—were identified via forward stepwise logistic regression and incorporated into the nomogram. The model demonstrated excellent performance, with AUCs of 0.902 (0.857–0.938) in the training cohort and 0.903 (0.825–0.953) in the validation cohort, significantly outperforming APACHE IV according to the DeLong test. Further validation via Hosmer-Lemeshow test, calibration curves, NRI, IDI, and DCA confirmed the nomogram's superior calibration and clinical utility. As the first comprehensive predictive tool of its kind for spinal fracture patients, this nomogram offers improved mortality risk estimation and supports clinical decision-making.

Keywords

Spinal Fractures, ICU Mortality, eICU Collaborative Research Database, Prognosis, Nomogram

1. Introduction

Spine fracture is a common traumatic disease, which can even cause disability and death when combined with spinal cord injury, seriously affecting patients' life and livelihood. With the advancement of human society and the frequent occurrence of motor vehicle collisions [1], the incidence of spinal fractures is on the rise, accounting for approximately 5-6% of total body fractures [2]. Because of its specific anatomical location and loading, the thoracolumbar junction is the most prevalent fracture location in the spine [3]. Vertebral fractures have been shown to be associated with reduced pulmonary function [4] and can increase the risk of in-hospital mortality by 60% [5]. Older adults and males also have an increased long-term mortality risk after traumatic spinal fractures compared with the general population [6]. Another study of older patients revealed a high risk of death and secondary fracture for vertebral fractures [7]. Once patients with spinal fractures need to be admitted to the intensive care unit (ICU), they often prove to have a complex pathophysiological state, combined with severe multiple compound injuries, massive bleeding or severe infections [8]. Patients' conditions

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Received: 21 August 2025; **Accepted:** 2 September 2025; **Published:** 23 September 2025

change rapidly and their vital signs are unstable, requiring access to life support such as ventilators or vasopressors. Therefore, there is a strong need to study patients with spinal fractures in the ICU to identify risk factors early and help improve prognosis.

The Acute Physiology and Chronic Health Evaluation IV (APACHE IV) scoring system is a commonly applied to critically ill patients [9], and many studies have found it to be superior to APACHE II and Acute physiology score III in the discrimination and calibration of predicting the in-hospital mortality risk in emergency-department and ICU patients, and also the duration of mechanical ventilators in critically ill patients [10, 11]. However, because critically ill patients have complex and diverse conditions, APACHE IV still has certain limitations in some diseases. For example, Lee et al. reported that APACHE IV did not have better performance on the in-hospital mortality in surgical intensive care units [12]. Nomograms can be used for multi-index combined diagnoses or predictions of disease onset or progression, and are generally constructed using establishing multiple regression models. Nomograms are being widely used in medical research, and physicians can used them to assess the corresponding risk of the patient and, by developing a personalized treatment and follow-up plan, to minimize the occurrence of adverse events. For example, the nomogram constructed by Li et al. had a clear effect in predicting the histiocytes of head and neck squamous cell carcinoma [13]. Nomograms can also accurately predict the postoperative overall survival and recurrence rates of gastric cancer patients [14].

Based on the APACHE IV scoring system, the present study aimed to establish a more-specific nomogram for the ICU mortality risk of patients with spinal fractures, to help identify patients with a high mortality risk, and to facilitate clinicians to monitor changes in the conditions of patients so that appropriate treatment measures can be applied in a timely manner to improve prognoses and ICU mortality rates.

2. Methods

2.1. Data Source

All data for this study were from the publicly available and free eICU Collaborative Research Database (eICU-CRD) [15], which was provided by collaborators at Philips Healthcare and the Massachusetts Institute of Technology (MIT) Laboratory for Computational Physiology. It consists of data from various ICUs around the United States, covering the hospitalization-related data of over 200,000 patients admitted to critical-care units in 20 hospitals during 2014 and 2015, giving a significant number of samples for research investigations. MIT (Cambridge, MA) and Beth Israel Deaconess Medical Center (Boston, MA) both gave approval for the use of this database. All information about patient identities was recoded in this database, eliminating the need to obtain informed consent from the patients. The eICU-CRD can be accessed by researchers who have attended the required courses and completed the corresponding assessments.

2.2. Study Population

All patients with spinal fractures according to International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) from the eICU-CRD were included in this study, and only the first data values of readmitted patients were used. Patients with unclear outcomes were excluded.

The "patientunitstayid" parameter of the patients with spinal fractures in the database was the unique identifier, and it was used to extract the corresponding patient information: age, sex, race, Body Mass Index (BMI), APACHE IV score, ICU admission source (emergency department or others), unit type at first admission [medical intensive care unit (MICU)/surgical intensive care unit (SICU) or others], fracture site (cervical spine, thoracic spine, lumbar spine, sacrum), combined with other fractures, combined with spinal cord injury, whether surgery was performed before admission to ICU; intervention methods (ventilator and vasopressor use within 24 hours of ICU admission), comorbidities [stroke, congestive heart failure (CHF), hypertension, chronic obstructive pulmonary disease (COPD), renal failure, liver disease, diabetes, and cancer], vital signs monitored within 24 hours of ICU admission [heart rate (HR), mean arterial pressure (MAP), temperature, respiratory rate (RR), and arterial oxygen saturation (SaO_2)], and the results of the first laboratory tests performed after ICU admission [white blood cell (WBC), red blood cell (RBC), hemoglobin, hematocrit, red blood cell distribution width (RDW), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), platelet, potassium, sodium, chloride, calcium, bicarbonate, anion gap (AG), creatinine, urea nitrogen (BUN), glucose].

The outcome was whether patients with spinal fractures died in the ICU.

2.3. Statistical Analysis

We cleaned the data before proceeding with the analysis. Indicators with a missing data rate of more than 20% were excluded, and the remaining missing data were filled using multiple interpolation. This was accomplished using the "mice" package of R software.

Depending on whether the continuous variables fitted a normal distribution, they were reported as mean and standard deviation or median and interquartile range (IQR) values. Frequency and percentage values were used to report categorical variables, and chi-square or Fisher's exact tests were used to assess differences between cohorts.

Patients with spinal fractures included in the study were

randomized into training (70%) and validation (30%) cohorts. The above-mentioned factors were screened within the training cohort using forward stepwise logistic regression, and the results were expressed as dominance ratios and 95% confidence intervals (CIs). Before performing logistic regression, we estimated the multicollinearity between variables using the variance inflation factor (VIF) [16]. Variables with a VIF higher than 4 were removed due to issues with multicollinearity. After determining the independent prognostic factors, logical regression was performed again, with the findings used to develop a new nomogram model for predicting the probability of ICU mortality in patients with spinal fractures. Dynamic nomogram was also drawn.

The validation cohort was used to further internalize the performance of the nomogram. Several of the following indicators were used for internal validation of the nomogram. The area under the receiver operating characteristic (ROC) curve (AUC) was used to evaluate the differentiation abilities of the nomogram and APACHE IV models. DeLong tests further verified the difference between the ROC curves of the new nomogram and the APACHE IV models, with $P<0.05$ considered indicative of a significant difference. The Hosmer-Lemeshow test was used to evaluate goodness of fit for the nomogram. Integrated discrimination improvement (IDI) and net reclassification index (NRI) were used to compare whether the new nomogram improved on the APACHE IV scoring system. Decision-curve analysis (DCA) was used to assess the net gain of the nomogram compared with APACHE IV, and was used to assess the clinical applicability of the nomograms.

All data analyses in this study were performed using R software (version 4.1.0), and $P<0.05$ was considered statistically significant.

3. Results

This study ultimately included 1146 patients: 802 and 344 in the training and validation cohorts, respectively. The median ages in the training and validation cohorts were 56.00 years (IQR=38.00–74.00 years) and 54.00 years (IQR=34.00–69.00 years), respectively. There were more males in both cohorts: 63.6% and 64.0%, respectively. The median APACHE IV scores of patients in the two cohorts were 46.00 (IQR=32.00–66.00) and 43.00 (IQR=29.75–65.00), respectively. The cervical spine was the most common fracture site in both cohorts, accounting for 38.4% and 35.8% of fractures, respectively. In the training cohort and validation cohort, 6.4% and 4.4% of patients had a combined spinal cord injury, respectively. More than 50% of patients in both cohorts had combined other fractures, 52.2% and 57.8%, respectively. 13.4% and 15.0% of patients in each of the two cohorts had undergone surgical treatment prior to ICU admission. Sepsis was the most common comorbidity, presenting in 91.8% and 93.0% of patients, respectively.

The remaining baseline characteristics are listed in more detail in Table 1.

Table 1. *Baseline characteristics of the study population.*

level	Training cohort	Validation cohort	p-value
	802	344	
Age (year)	56.00 (38.00, 74.00)	54.00 (34.00, 69.00)	0.066
Gender (%)			0.960
Male	510 (63.6)	220 (64.0)	
Female	292 (36.4)	124 (36.0)	
Ethnicity (%)			0.949
White	672 (83.8)	287 (83.4)	
Others	130 (16.2)	57 (16.6)	
BMI (kg/m^2)	26.46 (23.34, 30.55)	25.88 (22.92, 30.05)	0.308
APACHE IV	46.00 (32.00, 66.00)	43.00 (29.75, 65.00)	0.086
Unit admit source (%)			0.228
Emergency department	589 (73.4)	265 (77.0)	
Others	213 (26.6)	79 (23.0)	
Unit type (%)			1.000
MICU/SICU	574 (71.6)	246 (71.5)	

level	Training cohort	Validation cohort	p-value
Others	228 (28.4)	98 (28.5)	
Site of fracture (%)			0.127
Cervical spine	308 (38.4)	123 (35.8)	
Thoracic spine	247 (30.8)	99 (28.8)	
Lumbar spine	214 (26.7)	97 (28.2)	
Sacrum	33 (4.1)	25 (7.3)	
Combined spinal cord injury (%)			0.233
No	751 (93.6)	329 (95.6)	
Yes	51 (6.4)	15 (4.4)	
Combined with other fractures (%)			0.093
No	383 (47.8)	145 (42.2)	
Yes	419 (52.2)	199 (57.8)	
Surgery (%)			0.542
No	682 (85.0)	298 (86.6)	
Yes	120 (15.0)	46 (13.4)	
Vasopressors (%)			0.721
No	732 (91.3)	311 (90.4)	
Yes	70 (8.7)	33 (9.6)	
Ventilator (%)			0.535
No	316 (39.4)	143 (41.6)	
Yes	486 (60.6)	201 (58.4)	
Comorbidities			
Sepsis (%)			0.547
No	736 (91.8)	320 (93.0)	
Yes	66 (8.2)	24 (7.0)	
CHF (%)			1.000
No	767 (95.6)	329 (95.6)	
Yes	35 (4.4)	15 (4.4)	
Hypertension (%)			0.895
No	719 (89.7)	310 (90.1)	
Yes	83 (10.3)	34 (9.9)	
Stroke (%)			0.668
No	773 (96.4)	334 (97.1)	
Yes	29 (3.6)	10 (2.9)	
COPD (%)			0.134
No	744 (92.8)	328 (95.3)	
Yes	58 (7.2)	16 (4.7)	
Renal failure (%)			0.064
No	791 (98.6)	344 (100.0)	

level	Training cohort	Validation cohort	p-value
Yes	11 (1.4)	0 (0.0)	
Liver disease (%)			0.428
No	796 (99.3)	339 (98.5)	
Yes	6 (0.7)	5 (1.5)	
Diabetes (%)			0.423
No	713 (88.9)	312 (90.7)	
Yes	89 (11.1)	32 (9.3)	
Cancer (%)			0.064
No	733 (91.4)	326 (94.8)	
Yes	69 (8.6)	18 (5.2)	
Vital signs			
Heart rate (min^{-1})	87.00 (73.00, 101.00)	87.00 (75.00, 101.00)	0.571
BP (mmHg)	121.00 (108.00, 137.00)	120.00 (107.00, 134.00)	0.289
Respiratory rate (min^{-1})	18.00 (15.00, 21.00)	18.00 (15.00, 21.00)	0.479
Temperature (°F)	98.40 (97.70, 99.10)	98.40 (97.90, 99.10)	0.643
SaO_2 (%)	98.00 (96.00, 100.00)	98.00 (96.00, 100.00)	0.422
Laboratory test results			
WBC (K/mcL)	10.20 (8.00, 13.29)	10.18 (7.90, 13.80)	0.829
RBC (K/mcL)	3.76 (3.24, 4.19)	3.62 (3.14, 4.11)	0.048
HGB (g/dL)	11.40 (9.80, 12.90)	11.30 (9.60, 12.70)	0.215
HCT (%)	34.30 (29.42, 38.30)	33.25 (28.67, 37.70)	0.062
MCHC (g/dL)	33.60 (32.80, 34.30)	33.70 (33.00, 34.40)	0.082
MCH (pg)	30.40 (29.20, 31.60)	30.50 (29.67, 31.60)	0.164
MCV (fL)	90.50 (87.00, 94.07)	91.00 (87.90, 93.90)	0.423
RDW (%)	13.80 (13.00, 14.70)	13.90 (13.10, 14.72)	0.560
Platelets (K/mcL)	176.00 (134.00, 226.75)	169.50 (130.00, 225.00)	0.204
AG (mmol/L)	9.85 (7.00, 12.00)	9.40 (7.00, 12.00)	0.637
Bicarbonate (mmol/L)	24.00 (22.00, 27.00)	25.00 (22.00, 27.00)	0.619
Sodium (mmol/L)	139.00 (137.00, 141.00)	139.00 (137.00, 141.00)	0.720
Potassium (mmol/L)	4.00 (3.80, 4.40)	4.10 (3.80, 4.40)	0.802
Chloride (mmol/L)	106.00 (103.00, 110.00)	106.00 (103.00, 110.00)	0.652
Calcium (mmol/L)	8.20 (7.70, 8.70)	8.10 (7.70, 8.50)	0.075
Glucose (mg/dL)	122.50 (105.00, 144.00)	125.50 (106.75, 148.25)	0.388
Creatinine (mg/dL)	0.81 (0.68, 1.08)	0.80 (0.67, 1.00)	0.155
BUN (mg/dL)	15.00 (11.00, 20.00)	14.00 (10.00, 20.00)	0.213

3.1. Nomogram Construction and Web-Based Calculator

The VIFs of each variable are listed in Table 2. The variables hematocrit, chloride, RBC, and MCH were not included in the logistic regression for variable screening due to the presence of multicollinearity. After deletion using logistic regression, the identified independent predictors of ICU mortality in patients with spinal fractures were age, BMI, APACHE IV score, unit admission source, ventilator use, combined spinal cord injury, sepsis, SaO_2, WBC count, HGB, and blood glucose. The ICU mortality risk increased by 1.022 (95% CI: 1.007–1.038) times for each 1-year increase in age, and by 1.050 (95% CI: 1.037–1.065) for each additional point on the APACHE IV score system. The mortality risk was 4.199 (95% CI: 1.639–12.629) times higher in patients who used a ventilator within 24 hours of ICU admission than in those who did not use a ventilator. Patients with combined spinal cord injury have 4.301 (95% CI: 1.332–12.555) times higher risk of ICU death than those without, and was 2.832 (95% CI: 1.186–6.574) times higher in patients with sepsis than those without. Blood glucose was also a risk factor for ICU mortality in patients with spinal fractures. Non-emergency ICU admission, BMI, SaO_2, and HGB were protective factors for ICU mortality (Table 2).

Table 2. *Multivariate logistic regression in the training cohort.*

	OR	95% CI		P-value
Age	1.022	1.007	1.038	0.005
BMI	0.915	0.859	0.968	0.003
APACHE IV	1.050	1.037	1.065	<0.001
Unit admit source				0.002
Emergency department	reference			
Others	0.292	0.129	0.620	
Ventilator				0.005
No	reference			
Yes	4.199	1.639	12.629	
Combined spinal cord injury				0.010
No	reference			
Yes	4.301	1.332	12.555	
Sepsis				0.016
No	reference			
Yes	2.832	1.186	6.574	
SaO_2	0.830	0.741	0.920	0.001
WBC	1.068	1.011	1.126	0.017
HGB	0.728	0.607	0.865	<0.001
Glucose	1.008	1.002	1.013	0.009

A nomogram containing the above-mentioned risk factors was constructed. The scores for all variables are summed to obtain the total score, which corresponds to the probability of ICU mortality in patients with spinal fracture (Figure 1). We further constructed a dynamic nomogram, based on this, we can more quickly derive the ICU mortality risk for patients with spinal fractures, and its page can be seen in Figure 2.

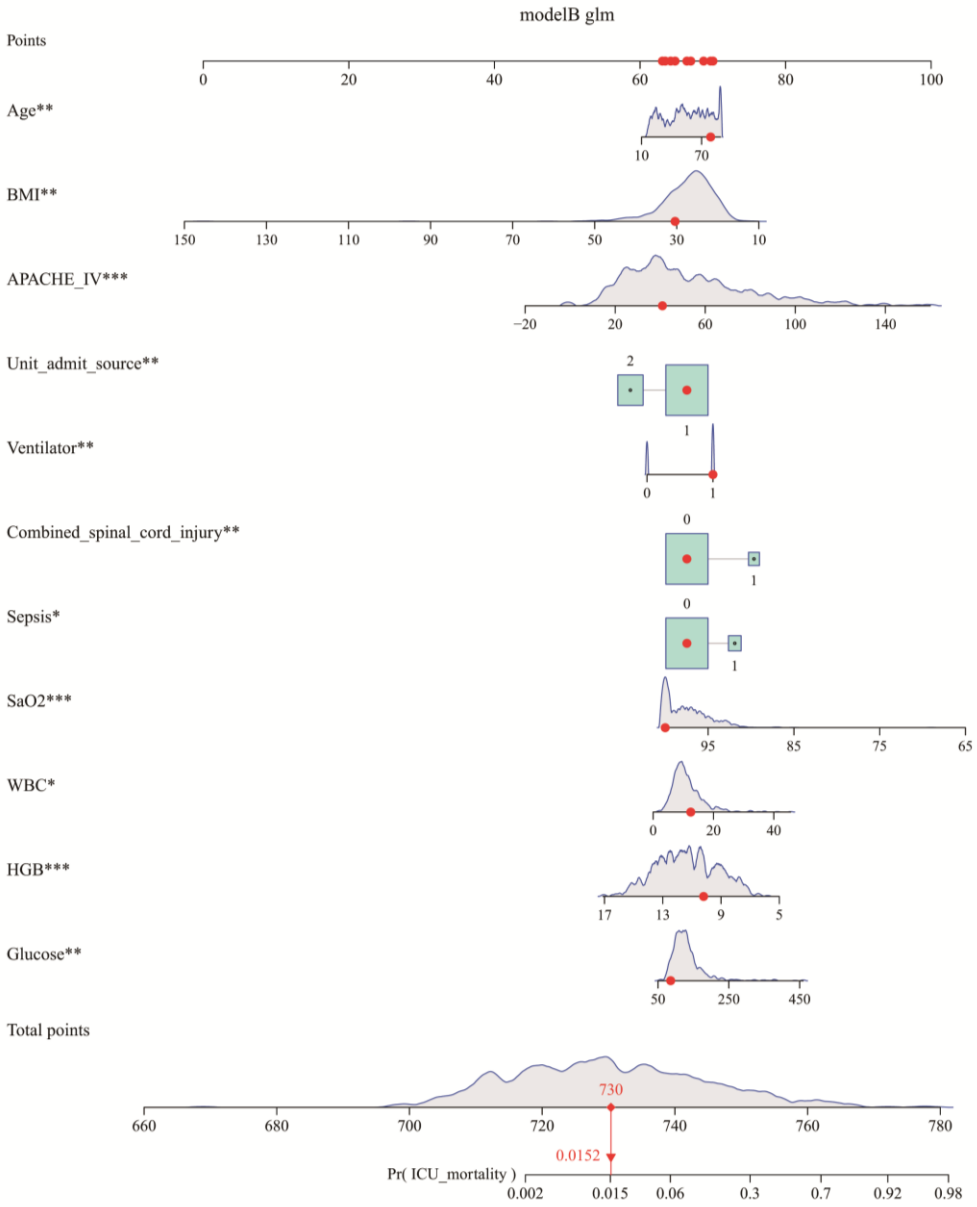


Figure 1. *Nomogram (model B) for predicting ICU mortality risk in patients with spinal fractures.*

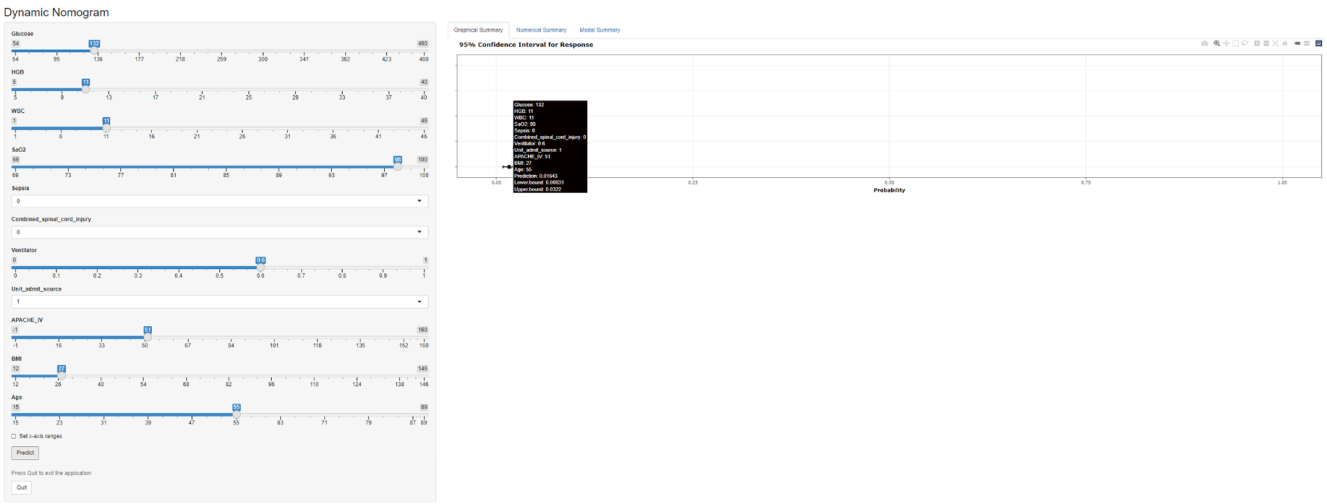
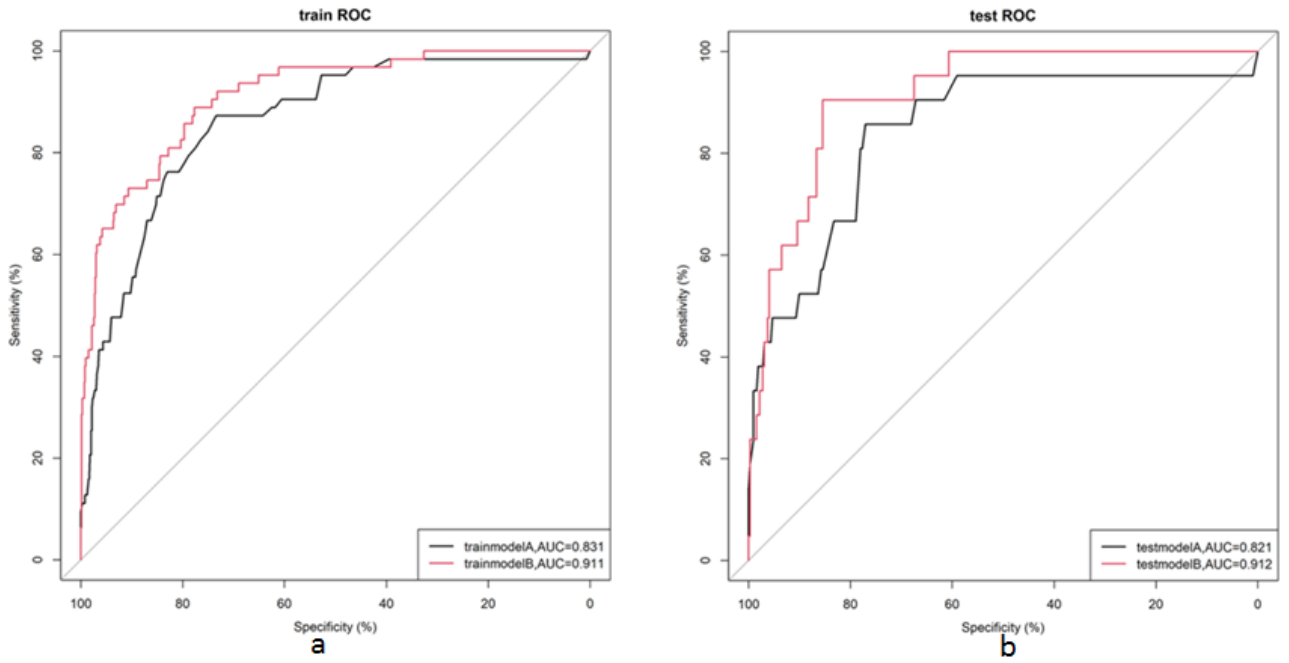


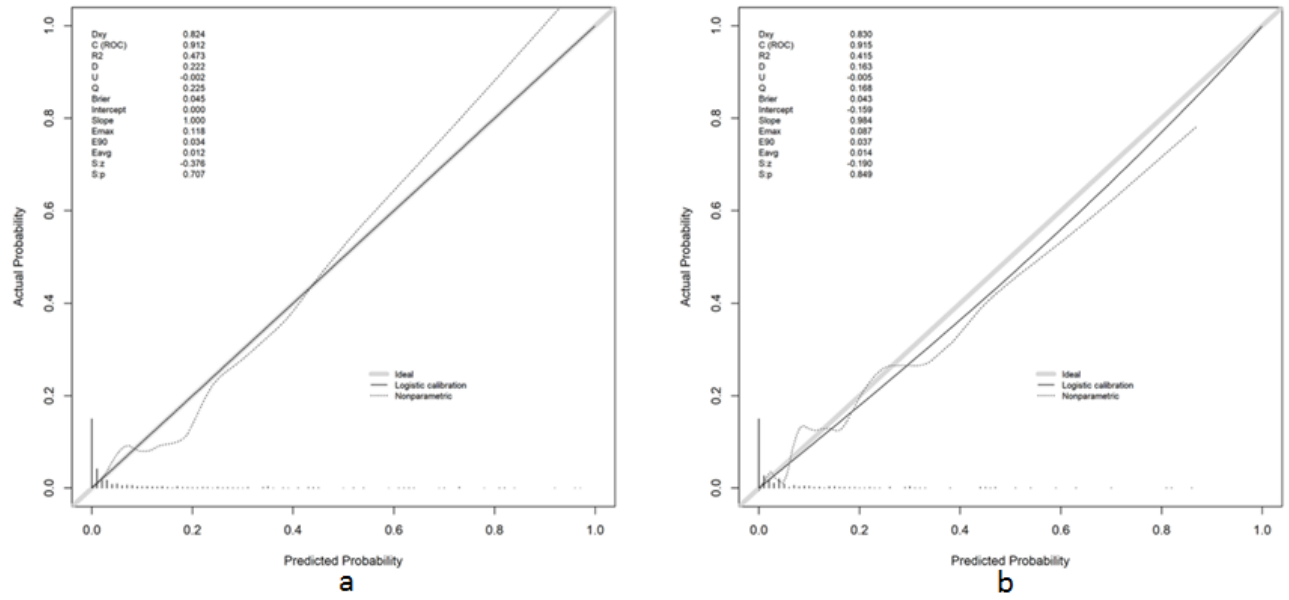
Figure 2. *The ICU mortality risk for patients with spinal fractures, and its page.*

3.2. Nomogram Validation



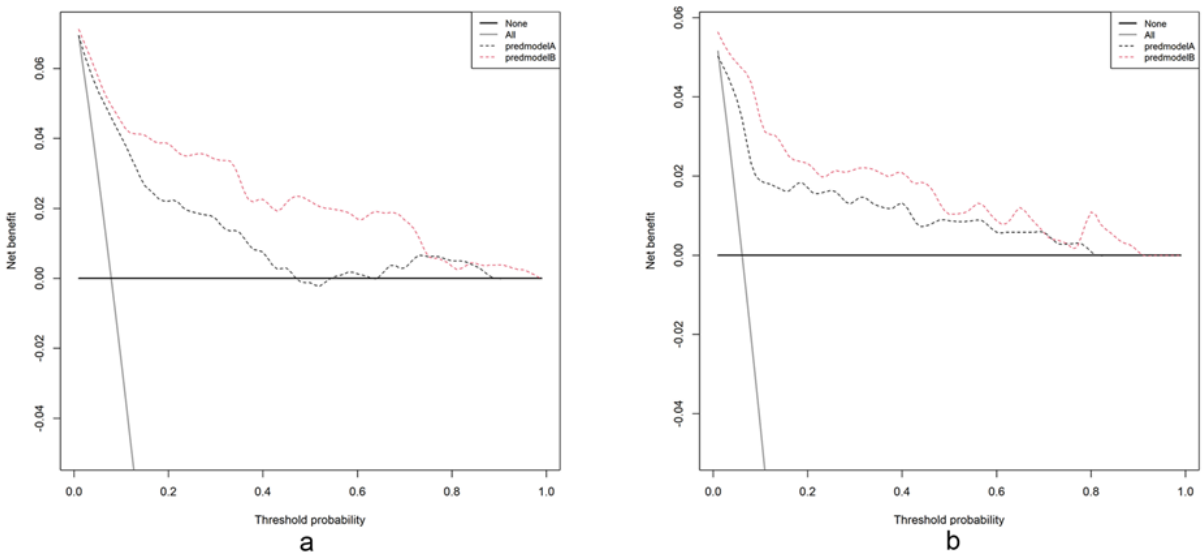
a for training cohort, b for validation cohort.

Figure 3. *ROC curves for the APACHE IV model (model A) and the nomogram (model B).*



a for training cohort, b for validation cohort.

Figure 4. *Calibration curves for the validation cohort and the training cohort.*



a for training cohort, b for validation cohort.

Figure 5. *Decision-curve analysis of the validation cohort and the training cohort. Model A represents the APACHE IV model, and model B represents the nomogram.*

Several of the metrics described above were used to compare the predictive power and performance of the nomogram we constructed using the APACHE IV scoring system. Figure 3 shows that the AUC values of the nomogram for the training and validation cohorts were 0.911 (95% CI: 0.871–0.943) and 0.912 (95% CI: 0.847–0.953), respectively, which were higher than those of the APACHE IV scoring system, which were 0.831 (95% CI: 0.774–0.904) and 0.821 (95% CI: 0.709–0.921), respectively. The results of the DeLong test were P=0.018 and P=0.043 in the training and validation cohorts, respectively, both of which are statistically significant, confirming that the nomogram did have a significantly higher ROC than the APACHE IV. Whether in the training cohort or the validation cohort, the Hosmer-Lemeshow test was not statistically significant (chi-square =14.126, P = 0.117; chi-square =3.642, P = 0.933), indicating that the new nomogram has a good fit. Compared with the APACHE IV system, the NRI values for the training and validation cohorts of the nomogram were 0.344 (95% CI: 0.252–0.675) and 0.478 (95% CI: 0.319–0.988), respectively; the corresponding IDI values were 0.148 (95% CI: 0.089-0.207) and 0.151 (95% CI: 0.058–0.243), respectively. These comparisons all indicate that the established nomogram had a significantly stronger performance than the APACHE IV scoring system.

Figure 4 shows the calibration curve for the nomogram. It is almost diagonal, indicating that the nomogram is more accurate in assessing risk. Finally, the clinical applicability of the nomogram was determined using DCA (Figure 5), which indicated that the new model has a greater net benefit than the APACHE IV system.

4. Discussion

Our study was based on the population with spinal fractures in the multicenter database eICU-CRD. The results indicated that age, BMI, APACHE IV score, unit admission source, mechanical ventilation use, combined spinal cord injury, sepsis, SaO_2, WBC count, HGB, and blood glucose were the factors influencing the ICU mortality of patients with spinal fractures. These variables were included in a nomogram for estimating the mortality risk of patients with spinal fractures during ICU hospitalization. We further constructed a dynamic nomogram, which can be obtained directly online and rapidly calculates a risk value, which is more convenient for clinical applications. Metrics including AUC, ROC, Hosmer-Lemeshow test, calibration curve, IDI, NRI, and DCA were also used to evaluate the validity of the nomogram.

From the nomogram it can be seen that age can affect the prognosis of patients with spinal fractures in ICUs, that is, the risk of death increases with age. Firstly, elderly patients in the critical care setting have a poorer nutritional status, more underlying diseases and their condition can deteriorate rapidly in a short period of time because of the reduced stability of various organ functions and the internal environment [17]. Also, the degeneration of the immune system and the impaired function of innate immune cells in the elderly make them more susceptible to infectious diseases [18]. Studies have demonstrated that infection is the leading cause of morbidity and mortality in the elderly among critically ill patients [19].

In our nomogram, BMI is heavily weighted, and as it increases the ICU mortality risk decreases in patients with spinal fractures. Malnutrition is closely related to the mortality of critically ill patients [20], and reducing catabolism, preventing

muscle atrophy, and maintaining good nutritional status are top priorities of nutritional support for critically ill patients in ICUs [21]. BMI is an indicator used to evaluate the nutritional status of the human body, and a study found that for critically ill patients with BMI <30 kg/m^2, providing appropriate energy support and protein supplementation reduces mortality risk [22]. A meta-analysis of 22 studies involving 88,051 ICU admissions found that obese (BMI ≥30 kg/m^2) and morbidly obese (BMI ≥40 kg/m^2) patients had lower in-hospital mortality rates than normal-weight patients [23]. Also, considering the pathogenesis of patients with spinal fractures, most obese patients have thicker layers of subcutaneous fat, which is beneficial to buffer the damage caused by injury to other organs of the body. Patients with low BMI should therefore receive clinical attention with a particular focus on providing appropriate nutritional support to reduce the mortality risk.

Spinal cord injury (SCI) is as well an independent risk factor for ICU outcome in patients with spinal fractures. SCI can lead to impairment of normal sensory, motor, or autonomic function [24], which not only increases acute adverse events in patients but is also associated with a worsening long-term prognosis [25]. Infection is a common threat to patients following SCI [26], with study revealing that 17% of patients associated with traumatic SCI die during acute hospitalization, and up to 80% of these deaths are due to complications associated with serious infections: pneumonia, wound infection, and sepsis [27]. In addition, a higher percentage of patients with SCI required assisted respiratory support. Ventilator use and a decreased SaO_2 can therefore indicate poor spontaneous breathing function, which may be partly related to SCI.

Of course, it cannot be ignored that ICU patients are at a relatively high risk of complications such as pulmonary infections because they cannot get out of bed in a timely manner. WBCs are an inflammation indicator [28], and WBC counts reflect the state of infection. Clinicians can use WBC counts to preliminarily determine whether there is infection in critically ill patients, find pathogenic bacteria in time, and use effective antibiotics to fight infection. Correspondingly, when the infection becomes severe, it can lead to sepsis [29], which is an independent risk factor for mortality in critically ill patients. According to the nomogram, elevated WBC counts combined with sepsis were associated with an increased ICU mortality risk in the patients with spinal fractures. Therefore, when the infection indexes of the patients are elevated, blood culture should be promptly checked for pathogenic bacteria and sensitive antibiotic treatment should be applied to prevent the further development of sepsis and improve the prognoses of patients.

The HGB level is an indicator commonly used in clinical practice to monitor the effective circulating blood volume. Trauma decreases the effective circulating blood volume and leads to the development of anemia. Studies have indicated that moderate or severe anemia has a strong connection to poor prognosis in severely injured patients [30]. A retrospective study of 250 severely traumatized patients found that low HGB levels were associated with mortality [31]. As can be observed in the present nomogram, as the amount of HGB decreases, the mortality risk of patients with spinal fractures increases. We should therefore pay close attention to changes in the HGB levels of patients, and use blood products appropriately to supplement the blood volume in order to prevent the occurrence of hemorrhagic shock.

The ICU mortality risk in patients with spinal fractures increases with the first increase in blood glucose after ICU admission. Hyperglycemia not only impedes wound healing but also increases surgical site infections [32], which in turn leads to increase in-hospital mortality for patients with fractures [33]. A previous study found that early hyperglycemia (blood glucose ≥200 mg/dL) was associated with increased infection rates and mortality in trauma patients [34]. Another study found that stress-induced hyperglycemia, rather than diabetic hyperglycemia, significantly increased the in-hospital mortality rates of trauma patients [35].

The number of patients with spinal fractures increases every year, and it is of great importance to present a model that can be used to make predictions about the mortality risk of this group of patients. Clinicians can effectively use the probabilities predicted by the nomogram developed in this study to communicate with patients and their families in a timely manner to help them fully understand the disease and their risk of death, and to jointly develop treatment plans to minimize the mortality risk.

5. Strengths and Limitations

The present nomogram is the first that we know of for predicting the ICU mortality risk of patients with spine fractures based on the first laboratory findings and comorbidities after ICU admission. Multiple metrics demonstrated that this nomogram performed better than the APACHE IV scoring system. We also constructed a dynamic nomogram. After entering the corresponding indicators, clinicians can immediately calculate the mortality risk of patients online, which is more convenient and efficient. However, this study also had certain limitations. First, this is a retrospective study. Second, the population of eICU-CRD was between 2014-2015, which was not timely enough. Third, we did not perform external validation. Fourth, due to database limitations, we were unable to determine whether the patient had an open or closed fracture; moreover, we were unable to know the specific surgical procedure the patient underwent prior to admission to the ICU. Also, this study was conducted on patients with spinal fractures in the ICU, and the next step regarding the larger population needs to be done as well.

6. Conclusion

This study builds the first comprehensive nomogram of spinal fractures based on the eICU-CRD and evaluates it using a number of metrics. The new nomogram we constructed can assist clinical staff in predicting the risk of ICU

mortality in patients with spinal fractures more accurately than using the APACHE IV scoring system.

Abbreviations

ICU	Intensive Care Unit
APACHE	Acute Physiology and Chronic Health Evaluation
APS	Acute Physiology Score
eICU-CRD	eICU Collaborative Research Database
MIT	Massachusetts Institute of Technology
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
BMI	Body Mass Index
MICU	Medical Intensive Care Unit
SICU	Surgical Intensive Care Unit
CHF	Congestive Heart Failure
COPD	Chronic Obstructive Pulmonary Disease
HR	Heart Rate
MAP	Mean Arterial Pressure
RR	Respiratory Rate
SaO_2	Arterial Oxygen Saturation
WBC	White Blood Cell
RBC	Red Blood Cell
RDW	Red Blood Cell Distribution Width
MCV	Mean Corpuscular Volume
MCH	Mean Corpuscular Hemoglobin
MCHC	Mean Corpuscular Hemoglobin Concentration
AG	Anion Gap
BUN	Blood Urea Nitrogen
IQR	Interquartile Range
CI	Confidence Interval
VIF	Variance Inflation Factor
ROC	Receiver Operating Characteristic
AUC	The Area Under the ROC Curve
IDI	Integrated Discrimination Improvement
NRI	Net Reclassification Index
DCA	Decision-Curve Analysis
SCI	Spinal Cord Injury

Ethics Approval and Consent to Participate

The study was an analysis of a third-party anonymized publicly available database with pre-existing institutional review board (IRB) approval.

Availability of Supporting Data

The data were available on the eICU Collaborative Research Database at https://eicu-crd.mit.edu/

Funding

This work was supported by the Guangzhou Key Medical Discipline and Guangzhou Municipal Science and Technology Bureau, Basic Research Program (2023A04J1903).

Conflicts of Interest

The authors declare no conflicts of interest.

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