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Original Article

Predictive value of Braden scale combined with hemoglobin and hematocrit for oral mucosal pressure injury risk in ICU patients

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Abstract: Objective: To evaluate the predictive value of the Braden scale and laboratory indicators for oral mucosal pressure injury (OMPI) in patients admitted to the Emergency Intensive Care Unit (ICU). Methods: A retrospective analysis was conducted on 238 intubated patients admitted to the First Affiliated Hospital of Anhui Medical University. Patients were divided into a training set (n = 166) and a validation set (n = 72). The training set was further classified into OMPI (n = 67) and non-OMPI (n = 99) groups. Clinical data were compared between the two groups, and a logistic regression model was constructed to develop a predictive nomogram. Model performance was assessed using discrimination and calibration metrics, and internal validation was performed with the validation cohort. Results: The training and validation sets were comparable. Significant predictors of OMPI included Braden scale score ($P < 0.001$), ICU length of stay ($P < 0.001$), intubation duration ($P = 0.039$), and hemoglobin ($P < 0.001$). Logistic regression identified Braden scale, intubation duration, hemoglobin, and hematocrit as independent risk factors. Conclusion: The combination of Braden scale score, hemoglobin, and hematocrit demonstrated good predictive value for OMPI in EICU patients.

Keywords: Tracheal intubation, oral mucosal pressure injury, Braden scale, hemoglobin, hematocrit

Introduction

With advances in intensive care and airway management, mechanical ventilation has become a standard respiratory support technique for critically ill patients in intensive care units (ICUs) [1]. Transoral intubation is the most commonly used method, accounting for over 96% of all tracheal intubations due to its ease of learning and operational simplicity [2-4].

Mucosal pressure injury (MPI) is a type of device-related pressure injury (DRPI) characterized by localized mucosal tissue damage caused by sustained pressure or shear forces from medical devices such as tracheal tubes, nasogastric tubes, and oxygen catheters [5]. Among these, oral MPI (OMPI) due to transoral intubation is the most prevalent [6, 7].

Patients undergoing transoral intubation are particularly vulnerable to OMPI due to impaired swallowing and coughing reflexes, disruption of the oral and respiratory tract defenses, altered oral microbiota, and mechanical irritation from tracheal tubes, bite blocks, fixation devices, and suctioning procedures [8, 9]. The reported incidence of OMPI ranges from 0.16% to 55.6%, typically occurring within 2 to 13 days post-intubation [7, 10]. Critically ill ICU patients, due to their compromised condition, are prone to recurrent and slow-healing OMPIs, which may lead to infection, adhesion, or ulceration. These complications exacerbate patient discomfort, cause dysphagia, increase medical costs, prolong hospitalization, and may strain the physician-patient relationship [11]. Therefore, early identification and prevention of OMPI are essential to improving care quality and nursing outcomes.

Identifying high-risk individuals is crucial for OMPI prevention; however, no standardized risk

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assessment tool currently exists for MPI or OMPI. The Braden Pressure Ulcer Risk Assessment Scale, widely used in clinical practice, was originally designed for assessing pressure injuries over bony prominences [12]. Given the structural and functional differences between skin and mucosa, its applicability to OMPI remains uncertain. This study thus aimed to investigate the predictive value of the Braden scale combined with laboratory parameters for OMPI in ICU patients, with the goal of informing the development of targeted risk prediction models and assessment tools for OMPI associated with transoral intubation.

Materials and methods

Study design

This retrospective study included patients admitted to the First Affiliated Hospital of Anhui Medical University between June 2022 and March 2024. Inclusion criteria were as follows: transoral tracheal intubation, age ≥ 18 years, ICU stay ≥ 24 hours, and the presence of an oral indwelling endotracheal tube. Exclusion criteria included a history of oral mucosal disease (which could interfere with observation), preexisting OMPI prior to ICU admission, and incomplete clinical data. A total of 238 eligible patients were enrolled and randomly assigned to a training set (n = 166) and a validation set (n = 72). In the training set, 67 patients developed OMPI, while 99 did not; in the validation set, 36 patients developed OMPI, and 36 did not. The study was approved by the Clinical Medical Research Ethics Committee of the First Affiliated Hospital of Anhui Medical University.

Data acquisition

Data were collected using the hospital's electronic medical records and an observation checklist. Variables included demographic information (sex, age, BMI), clinical characteristics (ICU length of stay, history of diabetes, fever, use of vasoactive agents, sedatives/analgesics, antibiotics, use of continuous renal replacement therapy (CRRT) and extracorporeal membrane oxygenation (ECMO), duration of tracheal intubation, etc.). Hematological indices collected included white blood cell count, albumin, hemoglobin, hematocrit, platelet count, and arterial oxygen partial pressure. Severity scores such as the Braden Scale and acute physiology and chronic health evaluation II scale (APACHE II) score were also recorded.

The Braden Scale, assessed by nurses within 24 hours of ICU admission, evaluates pressure injury risk across six subscales. Each subscale is scored from 1 to 4 (except friction/shear, scored 1-3), with total scores ranging from 6 to 23; lower scores indicate higher risk [13].

The APACHE II score, with a theoretical maximum of 71, reflects disease severity and complexity. Higher scores indicate worse prognosis and greater clinical complexity [14].

Statistical analysis

Continuous variables were presented as mean ± standard deviation. Group comparisons were performed using independent samples t-tests or nonparametric tests based on distribution normality. Categorical variables were reported as frequencies and percentages, and analyzed using the chi-square test. Univariate and multivariate logistic regression analyses were conducted to identify potential risk factors for OMPI in ICU patients.

A nomogram model was constructed using the training set to predict OMPI risk in intubated patients. Model performance was evaluated in terms of discrimination (ROC curves), calibration, and clinical utility via decision curve analysis (DCA). Predictive power of the Braden Scale, hemoglobin, and hematocrit was also assessed. A significance level of $\alpha = 0.05$ was used. Statistical analyses were performed using SPSS version 27.0, with two-sided *P*-values < 0.05 considered statistically significant.

Results

Comparison of general data between the training set and validation set

As shown in **Table 1**, the incidence of OMPI was 40.36% in the training set and 50.00% in the validation set. No statistically significant differences in baseline clinical characteristics were observed between the two sets (all P > 0.05) (**Table 1**).

Comparison of general data OMPI and non-OMPI patients in the training set

As shown in **Table 2**, among the 166 patients in the training set, 67 developed OMPI. In this

Table 1. Comparison of general data between training and validation sets

	Validation set (n = 72)	Training set (n = 166)	$t/Z/\chi^2$	*P* value
Sex, n (%)			0.98	0.323
Male	42 (58.33)	108 (65.06)		
Female	30 (41.67)	58 (34.94)		
Age, n (%)			0.55	0.761
< 45	8 (11.11)	21 (12.65)		
45-64	26 (36.11)	66 (39.76)		
≥ 65	38 (52.78)	79 (47.59)		
BMI, n (%)			5.75	0.056
< 18.5	27 (37.50)	45 (27.11)		
18.5-24	42 (58.33)	99 (59.64)		
≥ 24	3 (4.17)	22 (13.25)		
Fever, n (%)			1.68	0.195
No	29 (40.28)	82 (49.40)		
Yes	43 (59.72)	84 (50.60)		
Diabetes, n (%)			1.69	0.194
No	57 (79.17)	118 (71.08)		
Yes	15 (20.83)	48 (28.92)		
Use of vasoactive drugs, n (%)			0.01	0.925
No	23 (31.94)	52 (31.33)		
Yes	49 (68.06)	114 (68.67)		
Use of sedative and analgesic drugs, n (%)			0.01	0.940
No	8 (11.11)	19 (11.45)		
Yes	64 (88.89)	147 (88.55)		
Use of antibiotics, n (%)			0.52	0.471
No	1 (1.39)	7 (4.22)		
Yes	71 (98.61)	159 (95.78)		
Use of CRRT, n (%)			0.03	0.855
No	58 (80.56)	132 (79.52)		
Yes	14 (19.44)	34 (20.48)		
Use of ECMO, n (%)			0.04	0.848
No	68 (94.44)	154 (92.77)		
Yes	4 (5.56)	12 (7.23)		
OMPI, n (%)			1.90	0.168
No	36 (50.00)	99 (59.64)		
Yes	36 (50.00)	67 (40.36)		
Hematocrit, Mean ± SD	30.82 ± 9.28	32.85 ± 7.74	-1.75	0.081
Braden scale, M (Q_1, Q_3)	12.00 (11.00, 13.00)	12.00 (12.00, 13.00)	-0.06	0.950
Length of ICU stay (d), M (Q_1, Q_3)	7.00 (5.00, 11.00)	7.00 (4.25, 10.75)	-0.73	0.465
APACHE II score, M (Q_1, Q_3)	20.50 (17.00, 24.00)	20.00 (17.00, 25.00)	-0.03	0.976
Tracheal intubation duration (h), M (Q_1, Q_3)	127.00 (66.50, 187.25)	120.00 (71.25, 168.00)	-0.33	0.744
White blood cell, M (Q_1, Q_3)	11.01 (8.12, 14.28)	10.07 (7.19, 14.25)	-1.01	0.311
Albumin, M (Q_1, Q_3)	31.85 (28.25, 35.35)	31.30 (27.60, 34.95)	-0.64	0.520
Hemoglobin, M (Q_1, Q_3)	101.00 (87.50, 120.00)	107.00 (90.00, 120.00)	-0.98	0.325
Platelet, M (Q_1, Q_3)	151.00 (71.75, 218.00)	136.50 (91.25, 206.50)	-0.13	0.897
Partial pressure of oxygen, M (Q_1, Q_3)	82.50 (68.30, 106.25)	88.00 (67.47, 115.28)	-0.59	0.558

BMI: body mass index, CRRT: continuous renal replacement therapy, ECMO: extracorporeal membrane oxygenation, OMPI: oral mucosal pressure injury.

group, 67.16% were male, and the age distribution was < 45 years (10.45%), 45-64 years (35.82%), and ≥ 65 years (53.73%). Corresponding figures in the non-OMPI group were

Table 2. Comparison of general data OMPI and non-OMPI patients in the training set

	Non-OMPI group (n = 99)	OMPI group (n = 67)	$t/Z/\chi^2$	*P* value
Sex, n (%)			0.22	0.640
Male	63 (63.64)	45 (67.16)		
Female	36 (36.36)	22 (32.84)		
Age, n (%)			1.76	0.415
< 45	14 (14.14)	7 (10.45)		
45-64	42 (42.42)	24 (35.82)		
≥ 65	43 (43.43)	36 (53.73)		
BMI, n (%)			0.45	0.800
< 18.5	28 (28.28)	17 (25.37)		
18.5-24	57 (57.58)	42 (62.69)		
≥ 24	14 (14.14)	8 (11.94)		
Fever, n (%)			0.84	0.358
No	46 (46.46)	36 (53.73)		
Yes	53 (53.54)	31 (46.27)		
Diabetes, n (%)			2.61	0.106
No	75 (75.76)	43 (64.18)		
Yes	24 (24.24)	24 (35.82)		
Use of vasoactive drugs, n (%)			1.04	0.308
No	34 (34.34)	18 (26.87)		
Yes	65 (65.66)	49 (73.13)		
Use of sedative and analgesic drugs, n (%)			0.44	0.508
No	10 (10.10)	9 (13.43)		
Yes	89 (89.90)	58 (86.57)		
Use of antibiotics, n (%)			0.07	0.798
No	5 (5.05)	2 (2.99)		
Yes	94 (94.95)	65 (97.01)		
Use of CRRT, n (%)			1.65	0.199
No	82 (82.83)	50 (74.63)		
Yes	17 (17.17)	17 (25.37)		
Use of ECMO, n (%)			0.00	1.000
No	92 (92.93)	62 (92.54)		
Yes	7 (7.07)	5 (7.46)		
Hematocrit, Mean ± SD	31.99 ± 7.31	34.12 ± 8.23	-1.75	0.081
Braden scale, M (Q_1, Q_3)	13.00 (12.00, 14.00)	12.00 (11.00, 12.50)	-3.50	< 0.001
Length of ICU stay (d), M (Q_1, Q_3)	6.00 (3.00, 9.00)	8.00 (6.00, 15.00)	-3.47	< 0.001
APACHE II score, M (Q_1, Q_3)	20.00 (16.00, 23.50)	21.00 (17.00, 25.00)	-1.17	0.242
Tracheal intubation duration (h), M (Q_1, Q_3)	110.00 (58.00, 167.50)	137.00 (88.50, 178.50)	-2.06	0.039
White blood cell, M (Q_1, Q_3)	10.08 (7.06, 14.80)	10.06 (7.42, 13.33)	-0.27	0.790
Albumin, M (Q_1, Q_3)	31.10 (27.00, 34.85)	31.80 (28.00, 35.40)	-0.96	0.337
Hemoglobin, M (Q_1, Q_3)	115.00 (102.00, 130.00)	90.00 (80.00, 109.00)	-6.28	< 0.001
Platelet, M (Q_1, Q_3)	151.00 (94.00, 214.50)	129.00 (72.50, 188.00)	-1.34	0.180
Partial pressure of oxygen, M (Q_1, Q_3)	95.00 (72.55, 118.00)	81.00 (65.80, 109.50)	-1.46	0.145

BMI: body mass index, CRRT: continuous renal replacement therapy, ECMO: extracorporeal membrane oxygenation, OMPI: oral mucosal pressure injury.

63.64% male and age distribution of < 45 (14.14%), 45-64 (42.42%), and ≥ 65 (43.43%). These differences were not statistically significant (all P > 0.05). However, patients with OMPI had significantly longer ICU stays (P < 0.001) and longer tracheal intubation duration (P = 0.039). Additionally, Braden scale scores (P < 0.001) and hemoglobin levels (P < 0.001) were significantly lower in the OMPI group. No significant differences were found between the

Table 3. Variable assignments for logistic regression analysis

	Type	Assignment
OMPI (Outcome)	Binary (Dependent)	Non-OMPI = 0; OMPI = 1
Sex	Binary	Male = 1; Female = 2
Age	Categorical	< 45 = 1; 45-64 = 2; ≥ 65 = 3
BMI	Categorical	< 18.5 = 1; 18.5-24 = 2; ≥ 24 = 3
Fever	Binary	No = 0; Yes = 1
Diabetes	Binary	No = 0; Yes = 1
Vasoactive medication	Binary	No = 0; Yes = 1
Sedative or analgesic medication	Binary	No = 0; Yes = 1
Antibiotics	Binary	No = 0; Yes = 1
CRRT	Binary	No = 0; Yes = 1
ECMO	Binary	No = 0; Yes = 1

BMI: body mass index, CRRT: continuous renal replacement therapy, ECMO: extracorporeal membrane oxygenation, OMPI: oral mucosal pressure injury.

groups in hematocrit, APACHE II score, white blood cell count, albumin, platelet count, or arterial oxygen partial pressure (all P > 0.05).

Univariate logistic regression analysis of OMIP in the training set

To further identify potential predictors of OMPI, univariate logistic regression analysis was conducted using OMPI occurrence as the dependent variable and all relevant patient data as independent variables. Variable coding and assignments are detailed in **Table 3**. As shown in **Table 4**, lower Braden scale scores (OR = 0.731, P = 0.002), lower hemoglobin levels (OR = 0.942, P < 0.001), longer intubation duration (OR = 1.005, P = 0.015), and longer ICU stay (OR = 1.051, P = 0.022) were significantly associated with an increased risk of OMPI.

Multivariate logistic regression analysis of OMIP in the training set

To identify independent risk factors for OMPI, variables with P < 0.1 from the univariate analysis were entered into a multivariate logistic regression model [15]. As shown in **Table 5**, independent predictors of OMPI included lower Braden scale scores (OR = 0.770, P = 0.046), lower hemoglobin levels (OR = 0.915, P < 0.001), higher hematocrit levels (OR = 1.176, P < 0.001), and longer intubation duration (OR = 1.008, P = 0.016).

Nomogram development for OMPI prediction

Based on the independent risk factors identified - lower Braden scale scores, lower hemoglobin, higher hematocrit, and longer intubation duration - a nomogram model was constructed to predict OMPI risk in tracheally intubated EICU patients (**Figure 1**). Since all patients in this study underwent oral intubation and a strong association was established between intubation duration and OMPI, the predictive contribution of intubation duration was not separately validated [6]. In the nomogram, each variable is assigned a point value proportional to its effect size, with the total score corresponding to the predicted risk of OMPI.

Evaluation of nomogram model

The predictive performance of the nomogram was assessed using multiple metrics. As shown in **Figure 2A**, the AUC was 0.874 (95% CI: 0.816-0.933) in the training set and 0.875 (95% CI: 0.785-0.965) in the validation set, indicating excellent discrimination. Calibration curves (**Figure 2B**) demonstrated good agreement between predicted and observed probabilities. DCA (**Figure 2C**) showed that the nomogram provided a high net clinical benefit across a wide range of threshold probabilities, confirming its potential utility in clinical practice.

Discussion

As the most common form of MPI in the ICU, OMPI shares both similarities and differences with skin pressure injuries, warranting increased clinical attention. Currently, there are no dedicated risk assessment tools for OMPI either domestically or internationally. This study

Table 4. Univariate Logistic regression analysis of OMIP in the training set

	β	S.E	*P* value	OR (95% CI)
Sex				
Male				Reference
Female	-0.156	0.334	0.640	0.856 (0.445-1.645)
Age				
< 45				Reference
45-64	0.134	0.529	0.801	1.143 (0.405-3.223)
≥ 65	0.515	0.515	0.317	1.674 (0.610-4.595)
BMI				
< 18.5				Reference
18.5-24	0.194	0.369	0.599	1.214 (0.589-2.500)
≥ 24	-0.061	0.539	0.911	0.941 (0.327-2.709)
Fever				
No				Reference
Yes	-0.291	0.317	0.359	0.747 (0.401-1.392)
Diabetes				
No				Reference
Yes	0.556	0.346	0.108	1.744 (0.885-3.438)
Use of vasoactive drugs				
No				Reference
Yes	0.353	0.348	0.309	1.424 (0.721-2.814)
Use of sedative and analgesic drugs				
No				Reference
Yes	-0.323	0.489	0.510	0.724 (0.277-1.890)
Use of antibiotics				
No				Reference
Yes	0.547	0.852	0.521	1.729 (0.325-9.183)
Use of CRRT				
No				Reference
Yes	0.495	0.387	0.201	1.640 (0.768-3.502)
Use of ECMO				
No				Reference
Yes	0.058	0.608	0.924	1.060 (0.322-3.491)
Braden scale	-0.313	0.100	0.002	0.731 (0.601-0.890)
APACHE II score	0.034	0.026	0.196	1.034 (0.983-1.089)
White blood cell	0.007	0.029	0.818	1.007 (0.951-1.066)
Albumin	0.023	0.025	0.366	1.023 (0.973-1.076)
Hemoglobin	-0.060	0.011	< 0.001	0.942 (0.922-0.962)
Hematocrit	0.037	0.021	0.083	1.037 (0.995-1.081)
Platelet	-0.002	0.002	0.167	0.998 (0.994-1.001)
Partial pressure of oxygen	-0.004	0.004	0.295	0.996 (0.988-1.004)
Tracheal intubation duration	0.005	0.002	0.015	1.005 (1.001-1.009)
Length of ICU stay (d)	0.049	0.022	0.022	1.051 (1.007-1.096)

BMI: body mass index, CRRT: continuous renal replacement therapy, ECMO: extracorporeal membrane oxygenation, OMPI: oral mucosal pressure injury.

analyzed predictive factors for OMPI associated with transoral intubation in 238 EICU patients and evaluated their predictive value for OMPI risk. Our findings indicate that Braden

Table 5. Multivariate Logistic regression analysis of OMIP in the training set

	β	S.E	*P* value	OR (95% CI)
Braden scale	-0.262	0.131	0.046	0.770 (0.595-0.996)
Hemoglobin	-0.089	0.015	< 0.001	0.915 (0.889-0.943)
Hematocrit	0.162	0.045	< 0.001	1.176 (1.076-1.285)
Tracheal intubation duration	0.008	0.003	0.016	1.008 (1.001-1.014)

OMPI: oral mucosal pressure injury.

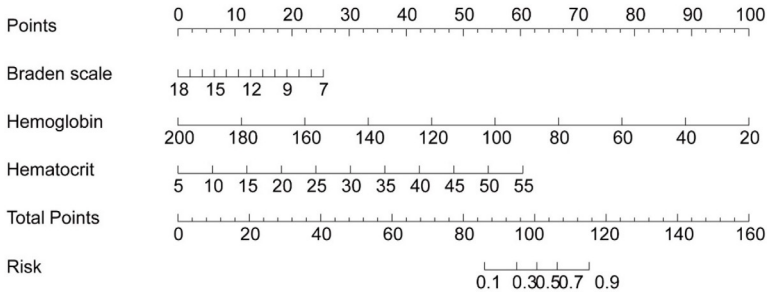

Figure 1. Nomogram prediction model.

score, hemoglobin, and hematocrit are significant predictors of OMPI, and their combined use demonstrates strong predictive efficacy, underscoring their importance in early prevention and intervention strategies.

Previous studies have shown that the Braden scale exhibits variable reliability, validity, and cut-off values when used in ICU settings, and should therefore be applied with caution [12, 16]. Despite these limitations, its utility lies in identifying patients at high risk for pressure injuries and guiding preventive care [12]. Adibelli et al. [17] confirmed the Braden scale as a reliable and valid tool for pressure injury risk assessment in ICU patients. Consistent with these findings, our study supports the Braden scale's predictive value in identifying OMPI risk among transorally intubated patients in the EICU.

Hemoglobin, a key protein responsible for oxygen transport in red blood cells [18], plays a vital role in maintaining tissue oxygenation. Low hemoglobin levels can result in tissue hypoxia, increasing the risk of pressure injuries [19]. Song et al. [20] highlighted hemoglobin as a marker of hemodynamic status and an important risk factor for pressure injury, suggesting its potential inclusion in future predictive models. In our study, low hemoglobin was independently associated with an increased risk of OMPI, demonstrating good predictive value.

Hematocrit, the proportion of red blood cells in whole blood, typically comprises about 40% of total blood volume [21]. When hemoglobin levels fall below normal, tissue oxygenation may be compromised [22]. Additionally, inflammatory mediators released after mucosal injury can trigger systemic inflammation [23]. Hematocrit may also serve as a marker of oxidative stress, as inflammation can impair erythropoiesis and reduce red cell survival [24, 25]. Choi et al. [11] identified hematocrit as a risk factor for upper OMPI. Interestingly, our study found that OMPI patients had both lower hemoglobin and higher hematocrit levels - an apparently contradictory finding. We hypothesize that this may be attributed to hypoxia and dehydration frequently observed in EICU patients [21].

Although some studies have identified the APACHE II score as a predictor of MPI and OMPI in ICU patients [26, 27], our results did not show a significant difference in APACHE II scores between the OMPI and non-OMPI groups. APACHE II, a revised version of the original APACHE system proposed by Knaus et al. [28], is widely used for evaluating disease severity and predicting ICU outcomes. While some studies [29, 30] support a positive association between APACHE II scores and pressure injury development, others, including a study on nasal MPI [31], report no such correlation. Our findings align with the latter, suggesting that APACHE II may not be a reliable predictor for OMPI in this specific context.

This study has several limitations. First, it is a retrospective study with a relatively small sample size, which may limit generalizability. Future studies with larger, multicenter cohorts are needed to enhance predictive accuracy. Se-

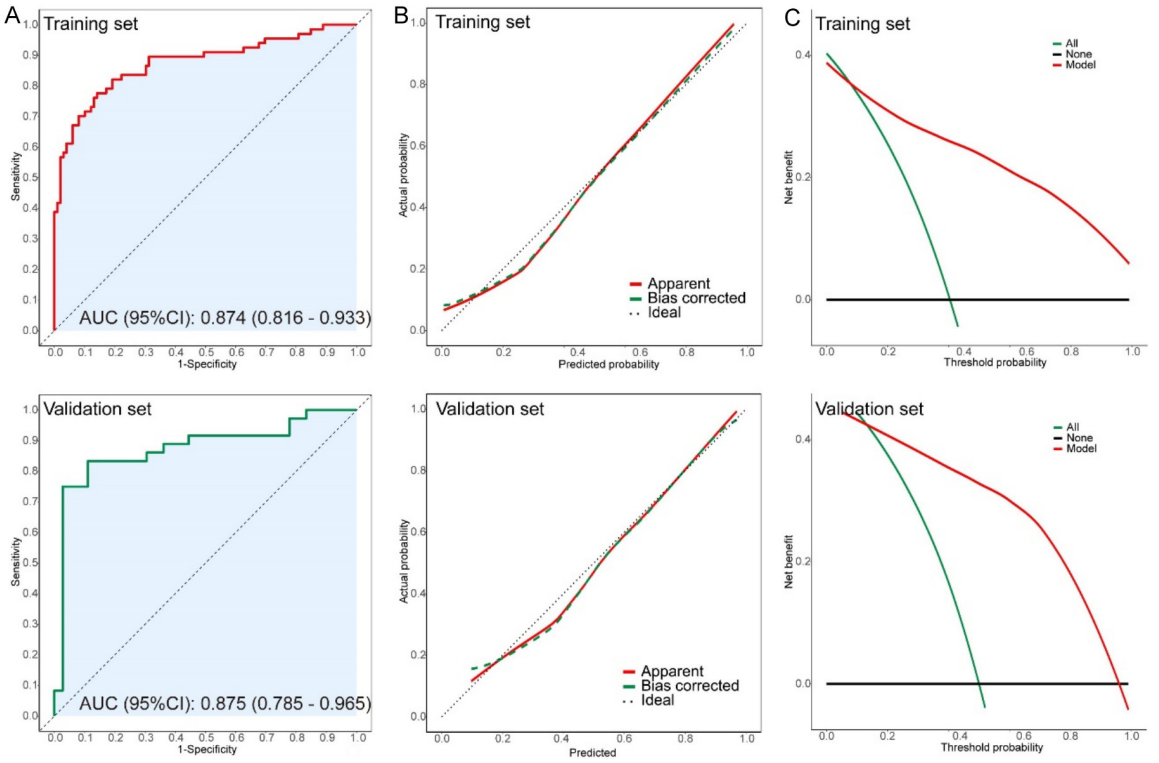

Figure 2. ROC, Calibration curves, and DCA curves for training and validation sets. A: ROC curves; B: Calibration curves; C: DCA curves. ROC: receiver operating characteristic, DCA: decision curve analysis.

cond, the effect of hematocrit on OMPI risk remains complex and requires further investigation. Third, while the nomogram was internally validated, external validation using independent cohorts or public databases is essential to confirm its robustness and applicability.

In conclusion, Braden score, hemoglobin, and hematocrit were identified as significant predictors of OMPI in ICU patients. Their combined application yields high predictive accuracy, offering valuable insight for early prevention and intervention strategies aimed at reducing patient discomfort and improving clinical outcomes.

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Disclosure of conflict of interest

None.

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