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Establishment and Validation of a Nomogram Clinical Prediction Model for Nosocomial Candidemia: An 18-Year Retrospective Analysis

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Background: Nosocomial candidemia is a life-threatening condition, and the incidence has increased in recent years. Thorough epidemiological data is still lacking in China.

Methods: A retrospective cohort study was conducted to investigate the patients admitted to Zhongshan Hospital Xiamen University from 1 January 2004 to 31 December 2022. This study included 205 individuals who were diagnosed with candidemia as subjects. Additionally, 303 cases with blood cultures were negative during the same period and were from the same department as a control group. We randomly assigned them to the training and validation groups in a 7:3 ratio. The least absolute shrinkage and selection operator regression, univariate and multivariate logistic regression analyses were used to filtrate independent factors associated with nosocomial candidemia. A nomogram model was established based on the selected variables. Receiver operating characteristic (ROC) curve, calibration plots and decision curve analysis (DCA) were used to evaluate clinical utility.

Results: Two hundred and five nosocomial candidemia patients were reported, containing a high proportion of *Candida albicans* (n = 91,44.39%), followed by *Candida parapsilosis* (n = 40, 19.51%), *Candida tropicalis* (n = 37,18.05%), *Candida glabrata* (n = 23, 11.22%) and *Candida guilliermondii* (n = 9,4.39%). Multiple organ dysfunction syndrome (OR = 10.372, 95% CI: 4.745–24.14 $P < 0.001$), increased urea nitrogen of serum (OR=1.088,95% CI: 1.039–1.144 $P<0.001$), decreased albumin of serum (OR = 0.922 95% CI: 0.850–0.997 $P=0.045$), mechanical ventilation (OR=4.074,95% CI: 1.397–12.77 $P=0.012$), central venous indwelling catheter (OR=7.422,95% CI: 3.189–18.41 $P<0.001$) and solid tumor (OR = 3.036 95% CI: 1.276–7.359 $P=0.012$) were identified as independent risk factors of candidemia. The area under the curve (AUC) of the nomogram model was 0.925 (95% CI: 0.898–0.952) in the training group and 0.946 (95% CI: 0.881–0.963) in the validation group. The calibration curve revealed good agreement between the probability and the observed values. DCA indicated that this nomogram might be clinically beneficial.

Conclusion: The nomogram including multiple organ dysfunction syndrome, elevated blood urea nitrogen, decreased albumin, mechanical ventilation, central venous indwelling catheter and solid tumor could provide reference value to clinicians for identifying nosocomial candidemia.

Keywords: candidemia, risk factors, nomogram model, ROC curve

Introduction

Candidemia is a serious fungal infection, and its incidence has increased significantly in recent years.[1] It extends the patient's hospitalization time, increases hospitalization costs, and is one of the leading causes of disease and death in patients with *Candida* infection.[2,3] The worldwide incidence of candidemia ranges between 0.3 and 8 per 1000 hospital admissions[4] and accounts for nearly 80% of all hospital-related fungal infections.[5] A comprehensive survey study showed that the overall 12-week mortality rate for candidemia was reported at 35.2%.[6] Immunocompromised critically ill

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patients with candidemia showed a hospital mortality rate of 60%.[7] A systematic review indicated that the mean total cost per patient with candidemia ranges from $48,487 to $157,574.[8] It is critical to identify a hospitalized patient with a high risk of candidemia to facilitate targeted monitoring and treatment of recipients.

Historically, candidiasis has been linked to immunocompromised and chronic inflammatory conditions.[9] Additional risk factors include extended hospital stays, the use of broad-spectrum antibiotics, surgery, indwelling central venous catheters, and biofilm formation, especially those used for full parenteral nutrition.[10–13] However, a recent study demonstrates that the risk variables contributing to candidemia's incidence and fatality rates will drastically alter throughout time and regional disparities.[10,14,15] It's critical to identify the predictors of candidemia in every given setting due to the regional variance and changing epidemiology of the disease. Finding the candidemia predictors in each specific setup is crucial.[16]

With this background, the current matched case–control study was carried out to determine independent factors and develop a predictive model at China's southeast coastal areas to ensure timely and appropriate treatment for affected patients.

Materials and Methods

Design of the Study

A retrospective cohort study was conducted to investigate the patients who were admitted to Zhongshan Hospital Xiamen University from 1 January 2004 to 31 December 2022. The diagnostic criteria for candidemia were based on the guidelines for the revised definition of invasive fungal disease (IFD) from the European Organizations for the Research and Treatment of Cancer/Mycoses Study Group (EORTC/MSG).[17] Exclusion criteria were included: (1) Age less than 18 years (2) Incomplete medical history data (3) Community-acquired infections of candidemia (4) Patients who had been treated with antifungal agents or broad-spectrum antibiotics before admission. (5) Exclude cases of mixed infections with other yeast-like fungi and bacteria. Finally, 205 candidemia cases that satisfied the criteria were included in the study. A total of 303 cases with blood cultures negative during the same period and were from the same distribution of department as a control group. The case group and controls were matched approximately in a 1:1.5 ratio. The study was approved by the Research Ethics Committee of the hospital by the Declaration of Helsinki guidelines (Reference number xmzsyyky 2024–020).

Data Collection

The demographic and clinical characteristics were based on electronic medical records and laboratory information systems. According to previous reports in the relevant literature, the following information was considered as possible risk factors for candidemia. Clinical characteristic baselines included age, gender, hypertension history, diabetes history, chronic obstructive pulmonary disease (COPD), solid tumor, hematologic malignancy, chronic renal failure, cerebrovascular disease, cardiovascular disease, organ transplantation, disseminated intravascular coagulation (DIC), rheumatism, multiple organ dysfunction syndrome (MODS) and inpatient days. Invasive procedures during hospitalization included central venous indwelling catheter, mechanical ventilation, urinary catheterization and gastrointestinal tract. Laboratory biomarkers included albumin, white blood count (WBC), neutrophil count, lymphocyte count, hemoglobin, platelet count (PLT), neutrophil-to-lymphocyte ratio (NLR), neutrophil-to-platelet ratio (NPR), lymphocyte-to-platelet ratio (LPR), creatinine (CREA), urea nitrogen (UREA), alanine transaminase (ALT), glutamic oxalacetic transaminase (AST).

Laboratory Identification of Candidemia

The blood culture samples were deposited in a fully automated blood culture system after collecting venous and arterial blood in vacuum blood culture bottles. (BACT/ALERT-3D BioMérieux, France before 2016 and BACTEC^{TM} FX, American 2016 to 2023). If the instrument sends a positive blood culture alarm, the specimens of positive blood bottles were examined under a microscope first, and then they were inoculated into blood plates and Sabouraud dextrose agar (Autobio Co Ltd) plates. MALDI-TOF MS identification was performed on a Microflex LT/SH (Bruker Daltonik,

Bremen, Germany) using the MBT Compass IVD 4.2 (Build 100). All *Candida* species were re-identified using MALDI-TOF MS in January 2023.

Statistical Analysis

All data were analyzed using SPPS26.0 statistical software (IBM SPSS Statistics, IBM Corporation, Armonk, NY, United States) and R software (version 4.2.0; R Foundation for Statistical Computing, Vienna, Austria). Categorical variables were presented as absolute values and relative percentages, and Fisher's exact test or the chi-square test were used to compare the two groups. Continuous variables were presented as mean ± standard deviation (comply with normal distribution) or median and interquartile range (Q1 Q3) (not comply with normal distribution), the difference between the two groups was applied to Student's *t*-test (comply with normal distribution) or Mann–Whitney *U*-test (not comply with normal distribution). *P* values less than 0.05 were considered statistically significant and were determined by two-tailed tests. Baseline description and statistic difference were automatically identified using the comparegroups package. LASSO regression was performed using the glmnet package. Multivariate logistic regression was performed using the glm package. Discriminatory analysis was performed using the ggROC package. Calibration was performed using rms package, DCA curves was performed using the rmda package and nomogram was constructed using the rms package. The statistical difference between the two groups of data should be reconfirmed using SPSS software.

The case group and control group were randomly sorted into a training group and a validation group in a random 7:3 ratio. Least absolute shrinkage and selection operator (LASSO) with ten-fold cross-validation and lambda 1 se as the criterion was applied to select the optimal combination of risk factors. Subsequently, univariate and multivariate logistic regression analysis was performed to explore the risk factor from the lasso regression. Variables with $P < 0.05$ were included in multivariate logistic regression. Variables with statistical significance ($P < 0.05$) in multivariable logistic regression were assessed for their effect using OR values and 95% confidence intervals. Additionally, the selected variables were used to construct the nomogram model with the rms package.

Clinical prediction models were internally validated using bootstrap (B = 1000 replications) and externally validated using a validation set. The receiver operating characteristic (ROC) curve, the area under the curve (AUC), calibration curve and decision curve analysis (DCA) were used to evaluate the discriminative ability of the nomogram model. The grading of the C-index was comparable to the AUC value.

Results

Characteristics of the Study Cohort

This study included 205 candidemia patients and 303 control groups, a flow diagram of the study design (Figure 1). During the 18 years study, 205 nosocomial candidemia patients were reported, containing a high proportion of *Candida albicans* (n=91,44.39%), followed by *Candida parapsilosis* (n = 40, 19.51%), *Candida tropicalis* (n=37,18.05%), *Candida glabrata* (n = 23, 11.22%) and *Candida guilliermondii* (n=9,4.39%) (Figure 2). In the candidemia group,147 (69.7%) cases were male, and the median age was 69 years. Using the R software package, a random split was performed with a ratio of 7:3, resulting in 355 cases for the training group and 153 cases for the validation group (Table 1). Thirty-two independent variables were analyzed to determine the risks of candidemia. The LASSO regression method is used to reduce the number of independent variables and ten-fold cross-validation is performed to select the most relevant variables based on lambda min. When λ=1- se, 16 predictive factors were found to be valuable (age, chronic obstructive pulmonary disease, solid tumor, hematologic malignancy, chronic renal failure, cerebrovascular disease, cardiovascular disease, central venous indwelling catheter, mechanical ventilation, urinary catheterization, albumin, neutrophil, hemoglobin, urea nitrogen, multiple organ dysfunction syndrome, inpatient days) (Figure 3A and B).

These 16 selected predictive factors were included in univariate and multivariate logistic regression analysis to screen the valuable factors (Table 2). Through univariate and multivariate analysis, the following variables performed statistical significance: multiple organ dysfunction syndrome (OR = 10.372, 95% CI: 4.745–24.14 $P<0.001$), urea nitrogen (OR=1.088,95% CI: 1.039–1.144 $P < 0.001$), albumin (OR=0.922,95% CI: 0.85–0.997 $P = 0.045$), mechanical

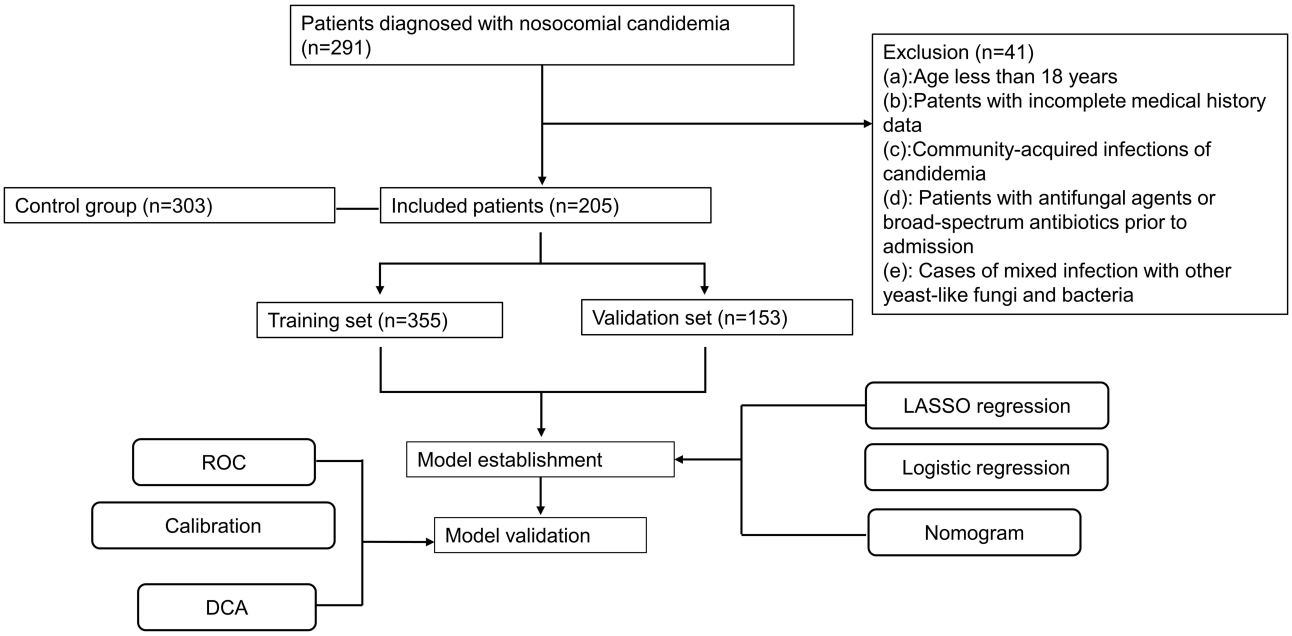

Figure 1 Research pathway diagram.

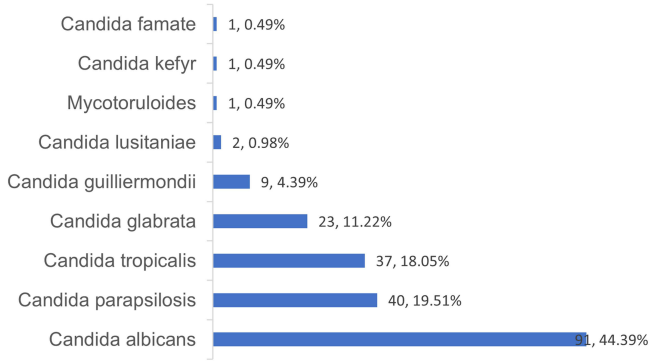

Figure 2 The proportion of *Candida* species of candidemia.

ventilation (OR = 4.074 95% CI: 1.397–12.77 $P = 0.012$), central venous indwelling catheter (OR = 7.422 95% CI: 3.189–18.41 $P < 0.001$) and solid tumor (OR = 3.036 95% CI: 1.276–7.359 $P = 0.012$).

Nomogram Predictive Model Construction

A nomogram model was created using the selected factors of multivariate logistic regression to predict nosocomial candidemia (Figure 4). The score for each independent factors was indicated on the upper scale, and the total scores of factors for each case of subjects were on the lower scale. The total score corresponded to the possibility of diagnosis at the bottom of the nomogram, indicating probability of participant's candidemia risk. Consider a patient with a solid tumor (25 points) who had invasive procedures such as mechanical breathing (52 points) and a central venous indwelling catheter (65 points) for example. The biochemical indicators revealed an albumin level of 35g/L (43 points) and a urea nitrogen level of 5.0 mmol/L (8 points); nonetheless, the patient did not have multiple organ failure during hospitalization. The total points on the nomogram were 193, equivalent to a probability of 75%.

Table 1 Demographic and Clinical Characteristics of Patients in Candidemia and Control Group

Variables (n%)	All (n=508)	Training Group (n=355)	Validation Group (n=153)	*P* value
Gender (male)	349 (68.70)	239 (67.32)	110 (71.89)	0.36
Years	69.0 [63.0–75.0]	68.0 [62.0–75.0]	69.0 [64.0–76.0]	0.192
Underlying conditions				
Hypertension	195 (38.38)	138 (38.87)	57 (37.25)	0.807
Diabetes	117 (23.03)	90 (25.35)	27 (17.64)	0.075
COPD	218 (42.91)	151 (42.53)	67 (43.79)	0.869
Solid tumor	113 (22.24)	73 (20.56)	40 (26.14)	0.204
Hematologic malignancy	24 (4.72)	19 (5.35)	5 (3.27)	0.431
Chronic renal failure	177 (34.84)	126 (35.49)	51 (33.33)	0.713
Cerebrovascular disease	124 (24.41)	89 (25.07)	35 (22.87)	0.678
Cardiovascular disease	209 (41.14)	145 (40.84)	64 (41.83)	0.913
Organ transplantation	2 (0.39)	1 (0.28)	1 (0.65)	0.512
DIC	6 (1.18)	6 (1.69)	0 (0.00)	0.185
Rheumatism	2 (0.39)	2 (0.56)	0 (0.00)	1
MODS	213 (41.93)	148 (41.69)	65 (42.48)	0.946
Invasive procedures				
CVC	218 (42.91)	150 (42.25)	68 (44.44)	0.719
Mechanical ventilation	101 (19.88)	73 (20.56)	28 (18.30)	0.642
Urinary catheterization	208 (40.94)	145 (40.84)	63 (41.17)	1
Gastrointestinal tract	164 (32.38)	117 (32.95)	47 (30.72)	0.695
Laboratory analytes				
Albumin (g/L)	31.52 [28.10–35.20]	31.7 [28.8–34.9]	31.66 [28.80–34.90]	0.437
WBC ($\times 10^9$/L)	9.19 [6.12–13.32]	9.32 [6.15–13.49]	8.87 [6.06–12.46]	0.583
Lymphocyte ($\times 10^9$/L)	1.51 [0.90–2.22]	1.51 [0.89–2.20]	1.54 [0.93–2.30]	0.596
Neutrophil ($\times 10^9$/L)	7.27 [4.36–11.38]	7.43 [4.28–11.72]	6.74 [4.60–11.00]	0.703
Hemoglobin (g/L)	95.00 [81.00–114.00]	95.00 [80.00–112.00]	95.00 [82.00–118.00]	0.363
Platelet ($\times 10^9$/L)	176.50 [104.00–269.25]	172.00 [96.00–258.00]	186 [112.00–290.00]	0.082
Neutrophil/Lymphocyte	4.99 [2.86–8.40]	5.00 [2.86–8.39]	4.78 [2.88–8.38]	0.959
Neutrophil/Platelet	0.04 [0.02–0.08]	0.04 [0.02–0.08]	0.04 [0.02–0.06]	0.153
Lymphocyte/Platelet	0.01 [0.01–0.01]	0.01 [0.01–0.01]	0.01 [0.00–0.01]	0.158
Creatinine (μmol/L)	73.15 [51.68–129.97]	75.50 [52.70–131.45]	69.50 [48.80–121.00]	0.153
Urea nitrogen (mmol/L)	5.55 [4.10–8.88]	5.47 [4.00–8.74]	5.57 [4.15–9.00]	0.553
ALT (U/L)	29.15 [14.80–56.90]	28.50 [14.00–55.70]	30.20 [15.80–58.90]	0.308

(*Continued*)

Table 1 (Continued).

Variables (n%)	All (n=508)	Training Group (n=355)	Validation Group (n=153)	*P* value
AST (U/L)	33.95 [20.90–64.00]	33.70 [20.30–62.90]	34.20 [24.60–69.00]	0.114
Length of stay	30.00 [20.00–42.00]	30.00 [20.00–41.00]	33.00 [19.00–44.00]	0.35

Abbreviations: COPD, Chronic obstructive pulmonary disease; DIC, Disseminated intravascular coagulation; MODS, Multiple organ dysfunction syndrome; CVC, Central venous indwelling catheter; WBC, White blood cell count.

Validation of the Nomogram

The effectiveness of the prediction model in the training set and validation set was evaluated using the receiver operating characteristic (ROC) curve (Figure 5A and B). The nomogram model's prediction performance was excellent, with an AUC of 0.925(95% CI: 0.898–0.952 cutoff value = 0.365 sensitivity = 0.866 specificity = 0.869) in the training set. The AUC of validation set was 0.946 (95% CI: 0.881–0.963 cutoff value = 0.337 sensitivity = 0.831 specificity = 0.939). Subsequently, the Bootstrap was used to resampling method repeated 1000 times, and calibration curves were plotted for the training set and validation set (Figure 6A and B). The Apparent and Bias-corrected lines showed that the Brier score was 0.100 with a slope of 1 and P = 0.915 in the training set. The Brier score was 0.096, the slope was 1.104 and P = 0.408 in the validation set. These results demonstrated a high degree of consistency between the anticipated probability of the nomogram model and the actual probability of occurrence, implying that the model had a certain degree of calibration.

Decision curve analysis (DCA) curves were plotted to assess the clinical utility of the nomogram model. DCA curves were used to evaluate the clinical utility of the nomogram model (Figure 7A and B). The DCA curves revealed that the net benefits for both the training and validation sets were much greater than the two extremes, implying that the model performs well in clinical settings. Furthermore, the loss-to-gain ratio was typically less than one, indicating good clinical value.

Discussion

Based on the previous studies,[18–20] we collected as many risk factors as possible for nosocomial candidemia. Hospitalized patients with candidemia often have underlying primary diseases, undergo invasive therapies during the hospital stay, and have impaired immune function. Various confounding factors must be considered as variables during

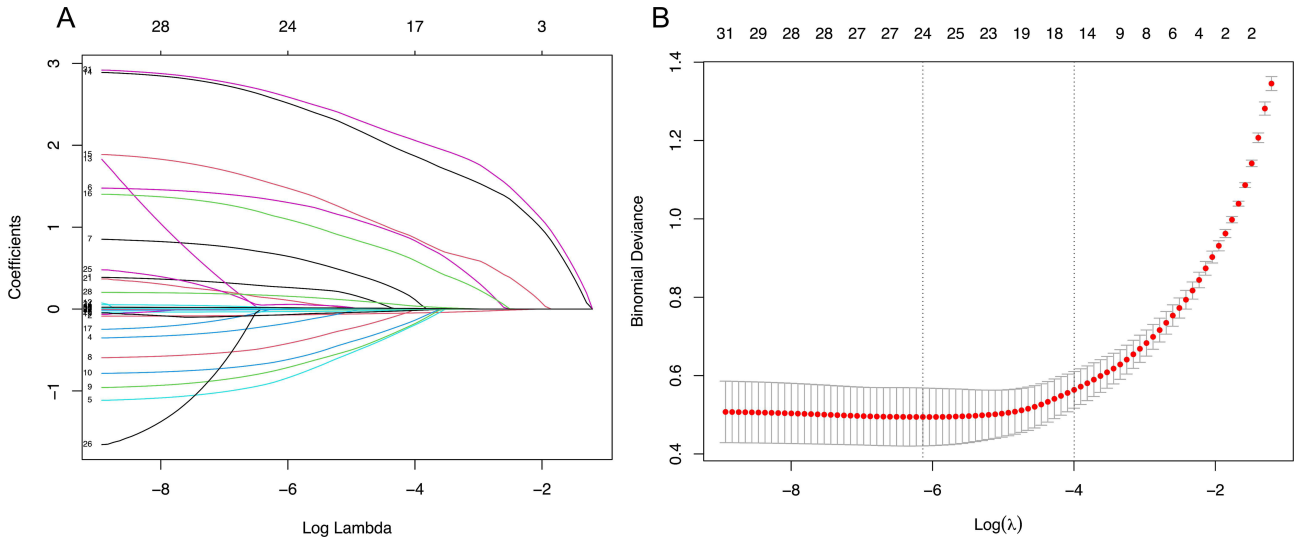

Figure 3 The screening of valuable variables by LASSO regression (**A**) regression coefficient path diagram (**B**) ten-fold cross-validation plot.

Table 2 Univariate and Multivariate Logistic Regression Analysis of the Factors Screened from the LASSO Regression

Variables	Univariate analysis			Multivariate analysis		
Characteristics	**OR**	**95% CI**	***P*-value**	**OR**	**95% CI**	***P*-value**
Years	0.936	0.914–0.956	<0.001*	0.909	0.873–1.140	0.054
Length of stay	1.030	1.018–1.043	<0.001*	1.022	1.003–1.047	0.051
MODS	14.988	8.947–25.830	<0.001*	10.372	4.745–24.140	<0.001*
Urea nitrogen	1.102	1.065–1.146	<0.001*	1.088	1.039–1.144	<0.001*
Hemoglobin	0.982	0.973–0.992	<0.001*	0.993	0.975–1.01	0.405
Neutrophil	1.005	0.972–1.038	0.783			
Albumin	0.909	0.871–0.946	<0.001*	0.922	0.850–0.997	0.045*
Urinary catheterization	4.407	2.802–7.009	<0.001*	2.038	0.862–4.848	0.104
Mechanical ventilation	18.723	9.503–40.590	<0.001*	4.074	1.397–12.770	0.012*
CVC	13.188	7.938–22.500	<0.001*	7.422	3.189–18.410	<0.001*
Cardiovascular disease	0.751	0.481–1.164	0.202			
Cerebrovascular disease	0.846	0.508–1.388	0.512			
Chronic renal failure	1.078	0.687–1.684	0.742			
Hematologic malignancy	1.900	0.746–4.905	0.175			
Solid tumor	2.798	1.658–4.769	<0.001*	3.036	1.276–7.359	0.012*
COPD	0.952	0.615–1.469	0.825			

Note: *Significant statistical difference ($P<0.05$).
Abbreviations: MODS, Multiple organ dysfunction syndrome; CVC, Central venous indwelling catheter; COPD, Chronic obstructive pulmonary disease.

this process. As to our study, initially, several factors were filtered using LASSO regression, followed by further selection using univariate and multivariate regression analysis. A nomogram model incorporating these six risk indicators to predict candidemia was developed and tested using the ROC curve, calibration curve, and DCA, resulting in high prediction accuracy and discriminative capacity. This retrospective cohort analysis revealed that solid tumor, central venous indwelling catheter, mechanical ventilation, decreased albumin of serum, increased urea nitrogen of serum and multiple organ dysfunction syndrome were risk factors for candidemia.

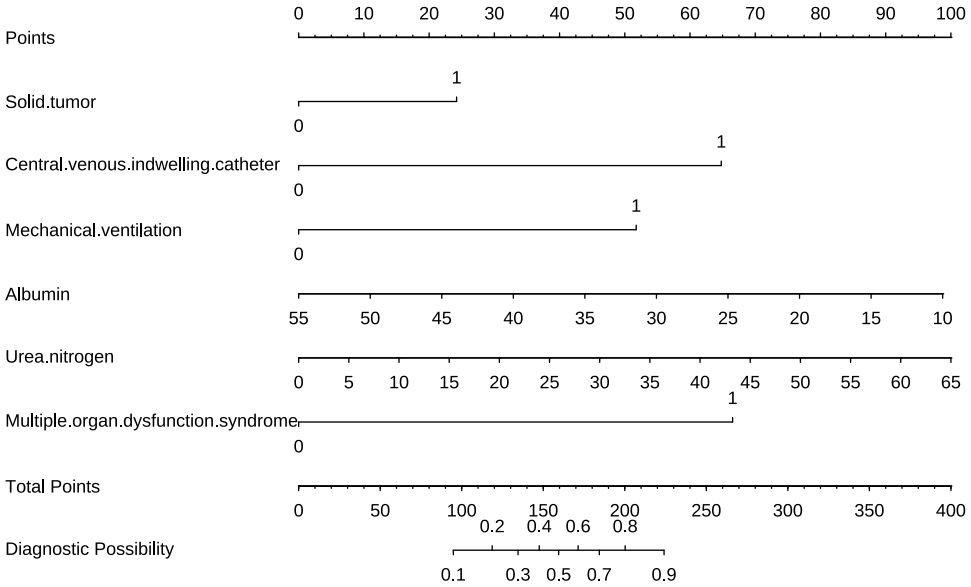

Figure 4 The diagnostic nomogram model for candidemia.

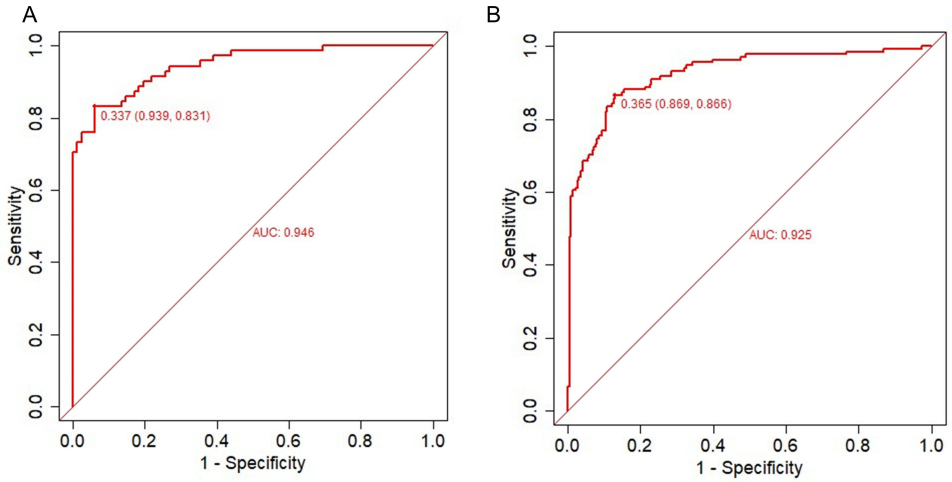

Figure 5 Receiver operating (ROC) curves of nomogram based on the data of the (**A**) training set and (**B**) validation set.

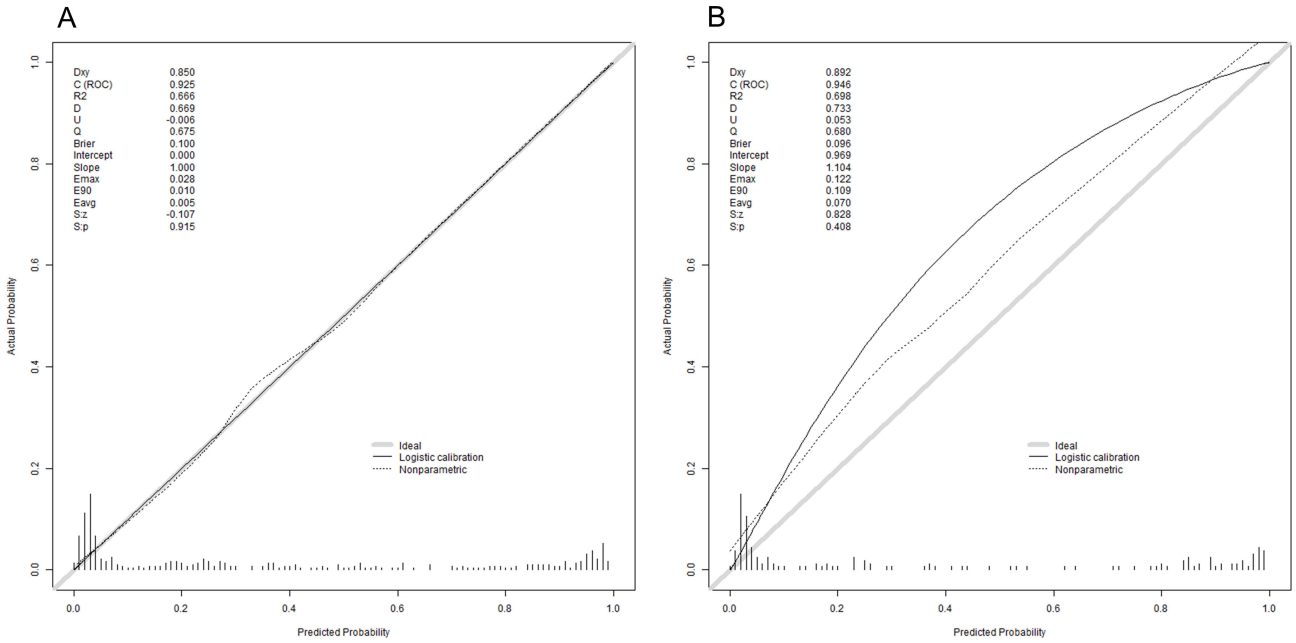

Figure 6 Decision curve analysis bootstrap resampling method repeated 1000 times for the prediction model: (**A**) training set (**B**) validation set.

Patients with solid tumors have a weaker immune system after chemotherapy or surgery, which raises the risk of candidemia.[21] Chemotherapy drugs may also damage the bone marrow, inhibit the production of white blood cells, and increase the risk of infection.[22] Furthermore, the stress response generated by surgery in solid tumor patients has a direct impact on tumor cells and modifies the tumor microenvironment, activating early and crucial immune system components. This stress response may cause immune system suppression, increasing the probability of candidemia.[23] Malignant tumors infect surrounding tissues and organs, spread via the circulation and lymphatic system, induce tissue damage, and facilitate candidemia.[24]

Central venous indwelling catheter is a major risk factor for candidemia, which is related to the formation of *Candida*'s biofilm, adhesion mechanisms, and immune evasion capabilities.[25] *Candida* can form a biofilm on the surface of central venous indwelling catheter. This biofilm is composed of *Candida* cells and extracellular matrix, which could protect planctonic form from the host immune system and antifungal drug attacks. Compared to free-floating *Candida,*

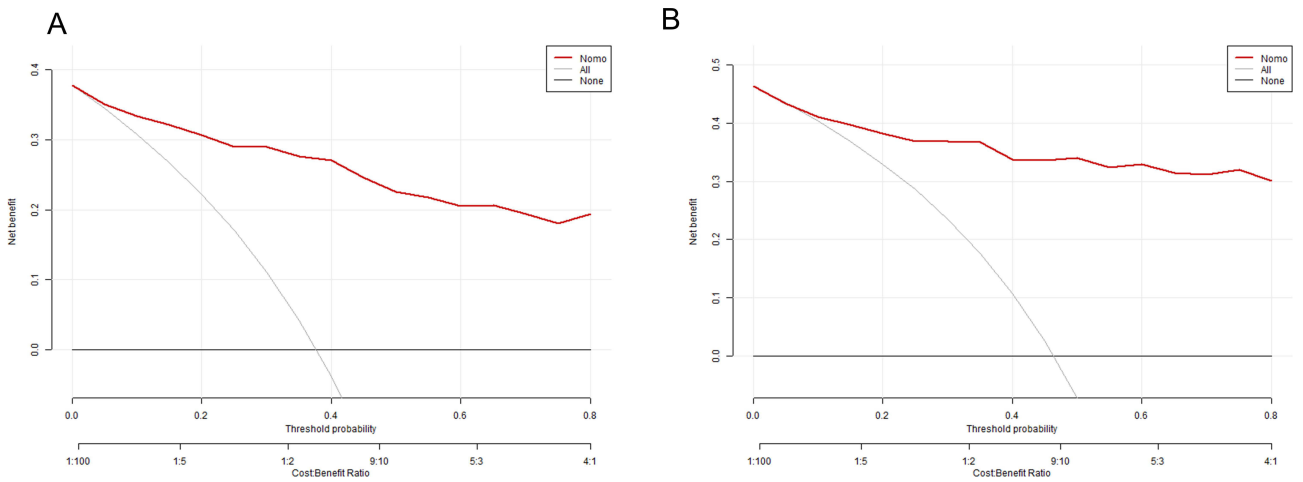

Figure 7 Decision curve analysis curve of the nomogram model based on (**A**) the training set and (**B**) the validation set.

Candida in the biofilm has higher drug resistance, increasing the risk of infection and the difficulty of treatment.[26] Philipp et al's research in 2020 found that *Candida* is attached to the central venous indwelling catheter surface by attachment factors such as Als3 protein.[27] The *Candida* cells on the surface of the central venous indwelling catheter coated with plasma exhibit higher adhesion ability than normal *Candida* cells. The Als3 protein plays a crucial role in the cell adhesion and directed flow mode of *Candida*, making it easier for them to adhere and form a biofilm. The biofilm structure formed by *Candida* helps it evade host immune surveillance and the effects of antifungal drugs. The presence of biofilm makes infections more difficult to treat, often requiring the removal of the central venous indwelling catheter to eliminate the source of infection.[28] Secondly, if sterile procedures are not strictly followed during central venous indwelling catheter insertion and maintenance, *Candida* may enter the circulation via the catheter interface or insertion site, resulting in bloodstream infections. Furthermore, long-term usage of central venous indwelling catheter can lead to *Candida* adhesion to the catheter's inner wall and biofilm formation, raising the risk of infection.[29]

Mechanical ventilation is widely used in the care of critically sick patients, who are more susceptible to infection. Candidemia is more likely to occur in those with severe disease, and the risk is further elevated in those who require mechanical ventilation.[7,30] Immunosuppressive medication and antibiotic usage linked with mechanical ventilation can change the patient's microbiome, raising the risk of candidemia.[31] Tan et al's report in 2016 showed that mechanical ventilation increases the risk of patients developing ventilator-associated pneumonia, and this infection often requires broad-spectrum antibiotic treatment, thereby further increasing the risk of *Candida* infection.[32] *Candida* colonization is a major precursor to candidemia. Patients on mechanical ventilation are more susceptible to *Candida* colonization and subsequent bloodstream infections because of inadequate airway care and decreased immunity.[33]

A nomogram study reveals that a reduction in lower albumin levels is positively connected with the incidence of candidemia. Mohamad et al's research in 2021 indicated that hypoalbuminemia is often associated with poor nutrition and the overall health status of patients.[34] Malnutrition affects the immune system, rendering patients more susceptible to infection like candidemia.[35] Low albumin levels may potentially be a sign of persistent inflammation. Chronic inflammation may produce immune suppression, rendering patients more susceptible to invasive infections such as candidemia.[36]

A rise in blood urea nitrogen (BUN) is typically associated with acute renal injury or chronic kidney disease. Renal insufficiency can cause an accumulation of metabolic waste in the body, weakening the immune system and rendering patients more vulnerable to candidemia.[37] Elevated blood urea nitrogen levels can indicate inflammation and malnutrition, in addition to kidney function concerns. Inflammation and starvation can reduce immunological function, increasing the likelihood of *Candida* infections.[38] Arihan et al in 2018 found that elevated blood urea nitrogen levels were associated with an increased risk of infection in critically ill patients, especially those receiving treatment in the Intensive Care Unit (ICU).[39] These patients have an increased incidence of candidemia.

Multiple organ dysfunction syndrome is frequently linked with severe infection or sepsis, which significantly suppresses the immune system and makes patients vulnerable to candidemia.[40] Patients with multiple organ dysfunction syndrome have a much lower immunological function, which diminishes the body's defense capacity.[41] Meanwhile, multi-organ failure is usually associated with hemodynamic instability, such as hypotension and decreased perfusion. This can promote tissue hypoxia and a reduction in local immune defense activity, increasing the risk of *Candida* growth in the bloodstream.[42] Patients with multiple organ failure usually suffer from malnutrition and metabolic abnormalities, which impair immune system function and lower the body's capacity to fight infections. This condition creates the optimal setting for *Candida* infection and propagation.[43]

The advantage of this study is that we identified the risk factors and constructed the nomogram model for the possibility of candidemia in the southeast coastal areas of China. The nomogram model enabled the medical staff easy to calculate the nosocomial candidemia for potential patients. As a result, this will help find patients with candidemia more quickly, which will allow for the creation of personalized plans to lower the number of cases and lessen their effects.

Several limitations need to be considered. First, the study used a single-center cross-sectional design and lacked validation with external data; if future prospective studies can be conducted across multiple centers, the effectiveness of the model can be further validated. Second, advancements in medical practices and infection control over time can lead to inconsistent data on candidemia infection in 18 years studies. Last but not least, our investigation excluded specific sepsis diagnostic biomarkers, such as interleukin and procalcitonin, because relevant tests were not done in our institution before 2016 and were vulnerable to antibiotic use.

Conclusion

In this study, we constructed a nomogram model for nosocomial candidemia including six variables based on underlying characteristics, invasive procedure and laboratory biomarkers. The variables containing solid tumor, central venous indwelling catheter, mechanical ventilation, decrease of albumin, increase of urea nitrogen, and multiple organ dysfunction syndrome. This nomogram may provide reference value for the clinical diagnosis of nosocomial candidemia.

Publisher's Note

Data Sharing Statement

All data generated or analyzed during this study are included in this published article and supplementary information files. Please contact the corresponding author for data requests.

Ethics Statement

The studies involving human participants were reviewed and approved by the Medical Ethics Committee of Zhongshan Hospital Xiamen University (No: xmzsyyky 2024-020). Written informed consent for participation was not required for this study by the national legislation and the institutional requirements. The patient data accessed was maintained with confidentiality.

This retrospective study involved no personally identifying information, posed minimal risk to the subjects without violating their rights or interests, and could not proceed if informed consent was required. Upon obtaining the data, the researcher assumes responsibility for maintaining confidentiality by replacing personal information with anonymous identifiers, and when publishing or presenting findings, aggregate data should be used to protect the privacy of subjects.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically

reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors affirm that the research was carried out without any commercial or financial associations that could be seen as a possible conflict of interest.

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