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ORIGINAL RESEARCH

Analysis of Risk Factors for Urinary Tract Infection in Ovarian Cancer Patients After Cytoreductive Surgery and Construction of a Nomogram Model

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Objective: The aim of this study was to analyze the risk factors of urinary tract infection in ovarian cancer patients after cytoreductive surgery(CRS) and construct a nomogram model.

Methods: A retrospective study was conducted on 349 ovarian cancer patients (all undergoing CRS) admitted to Meizhou people's hospital from August 2021 to August 2024. The patients were randomly assigned into modeling group and validation group in a 7:3 ratio (According to the random number table method). The modeling group was assigned into infected group and non infected group based on whether the patient developed urinary tract infection after CRS. Logistic regression was used to analyze influencing factors, and R software (R version 3.6.3 software and the rms package) was used to construct nomogram models. P<0.05 indicates a statistically significant difference.

Results: A total of 86 out of 349 patients developed infections, with an incidence rate of 24.64%. Among 244 patients in the modeling group, 61 cases developed infections, with an incidence rate of 25.00%. Logistic regression analysis showed that age, diabetes, tumor staging, number of catheter insertions, catheter retention time and postoperative hypoproteinemia were the risk factors for urinary tract infection after CRS in ovarian cancer patients (P<0.05). The area under the curve(AUC) of the modeling group was 0.950, and the H-L test showed χ^2=6.912, P=0.697. The AUC of the validation group was 0.970, and the H-L test showed χ^2=6.756, P=0.642. Decision curve analysis (DCA) curve indicated that the clinical value was higher when the probability was between 0.08 and 0.90.

Conclusion: The nomogram predicting the risk of postoperative UTI based on the identified risk factors demonstrated good discrimination and calibration. However, this model is still preliminary and requires external, multicenter validation before it can be applied in clinical practice.

Keywords: ovarian cancer, cytoreductive surgery, urinary tract infection, risk factors, nomogram

Ovarian cancer is a common malignant tumor and has the highest mortality rate among gynecological malignancies.[1] Due to the insidious onset of ovarian cancer and the high likelihood of tumor metastasis, most patients are diagnosed at an advanced stage, missing the optimal timing for surgical treatment and leading to increased mortality.[2] Currently, clinical treatment methods such as surgery and chemotherapy can effectively extend patient survival time.[3] Cytoreductive surgery (CRS) is a first-line treatment for advanced ovarian cancer, capable of significantly reducing tumor burden and improving survival rates. However, the surgical scope includes not only the ovaries and uterus but also necessitates the removal of pelvic and abdominal metastatic lesions (larger than 2 cm in diameter) and may involve urinary and intestinal vasculature, making the procedure highly challenging with frequent complications.[4,5] Urinary tract infection (UTI) is a common complication after CRS for ovarian cancer, potentially related to surgical methods and the unique urogenital

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structures in women, significantly impacting patients' quality of life.[6,7] Therefore, identifying influencing factors and implementing preventive measures in clinical practice can effectively improve patient prognosis.

Nomograms have clear advantages in the medical field as they transform complex multivariate analysis results into intuitive and visual tools. Clinicians can quickly estimate a patient's risk of developing a urinary tract infection using simple scale markings, without the need for complex calculations or programming. This straightforward and user-friendly approach greatly enhances clinical practicality, helping physicians make rapid judgments and decisions during diagnosis and treatment, thereby reducing the risk of infection.[8,9] Studies have found that a nomogram based on risk factors for catheter-associated urinary tract infections after radical hysterectomy for cervical cancer has been developed. This nomogram model offers several advantages, including simplicity, high diagnostic accuracy, and significant clinical value, and can assist in early clinical decision-making.[10] Some researchers have used machine learning-assisted ensemble analysis to predict postoperative urinary tract infection in elderly ovarian cancer patients. A predictive model developed using a random forest classifier can help identify elderly ovarian cancer patients who are at risk of developing postoperative urinary tract infections.[6] Given the lack of studies on UTIs after CRS for ovarian cancer patients using nomograms, this study aimed to investigate the risk factors for post-CRS UTIs in ovarian cancer patients and develop a nomogram model.

Materials and Methods

General Information

A retrospective selection was made of 349 ovarian cancer patients (all of whom underwent CRS) who were admitted to our hospital between August 2021 and August 2024. The sample size was estimated using the formula: $N = Z^2 \times [P \times (1-P)] / E^2$, where Z is the statistic, Z = 1.96 for a 90% confidence level; E is the margin of error, set at 5%; and P is the expected proportion, set at 0.5. Thus, $N = 1.96^2 \times 0.5 \times 0.5 / (0.05^2) \approx 384$. After excluding 35 patients due to missing data, 349 patients were finally included. According to a 7:3 ratio, patients were randomly assigned into a modeling group (244 patients) and a validation group (105 patients) using the random number table method. A random sequence was generated by SPSS software to ensure that the sequence was pattern-free and conformed to random distribution. Numbers from 0–9 in the random table were coded such that 0–6 were assigned to the modeling group and 7–9 to the validation group, ensuring a 7:3 allocation ratio. Patients in the modeling group were further categorized into infection and non-infection groups based on the occurrence of post-CRS UTIs. The case collection flowchart is shown in Figure 1. Inclusion criteria: (1) Meeting ovarian cancer criteria,[11] confirmed by pathology and imaging; (2) Clinical staging ≥ stage III, with fixed pelvic and abdominal masses; (3) Scheduled

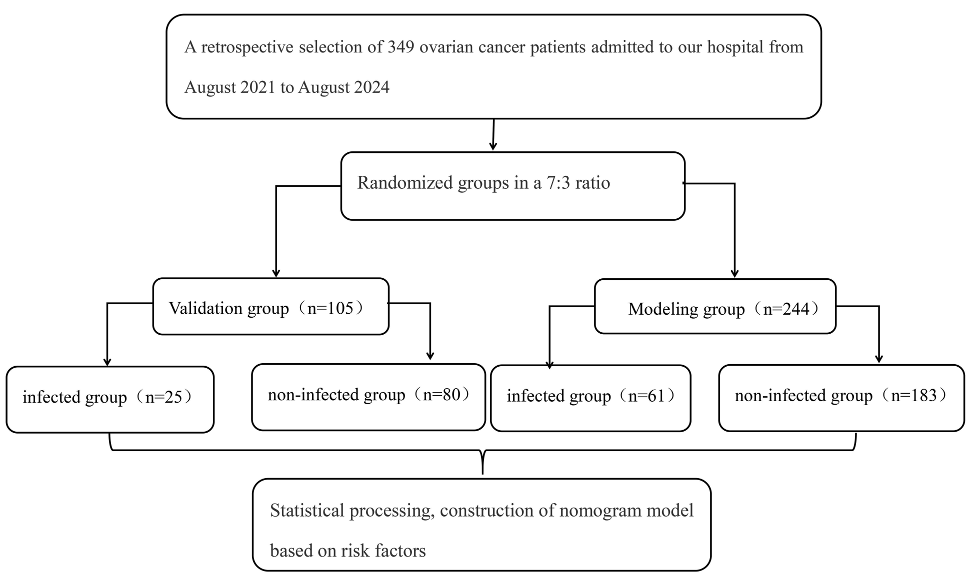

Figure 1 Case flow collection diagram.

CRS; (4) Complete clinical data available. Exclusion criteria: (1) Significant organ failure; (2) Other malignancies; (3) Immune dysfunction[Comprehensive assessment based on medical history collection, laboratory tests (immunoglobulin and complement levels), and treatment records]; (4) Acute or chronic infections before surgery; (5) Long-term use of immunosuppressants or corticosteroids; (6) Mental disorders or cognitive dysfunction. This study was approved by the hospital ethics committee.

Diagnosis of Postoperative Urinary Tract Infection

The diagnosis of urinary tract infection[12] was based on the presence of one or more of the following within 1 month after surgery during postoperative follow-up: (1) Postoperative urinary irritation symptoms (eg, frequent or urgent urination); (2) Positive urine culture results for pathogenic bacteria ($\geq 10^3$ CFU/mL); (3) White blood cell count ≥ 5 per high-power field in urine sediment microscopy.

Clinical Data

Clinical data were collected from the hospital's electronic medical record system (The selected patients all had complete clinical data), including age, body mass index (BMI), hypertension, diabetes, tumor stage, surgery duration, intraoperative blood loss, hospital stay, number of catheterizations, duration of catheter retention, postoperative hypoproteinemia, prophylactic antibiotic use, preoperative chemotherapy, timely urinary bag replacement, and UTI prevention education.

Statistical Analysis

Data were analyzed using SPSS 25.0. Categorical data were tested with the χ^2 test and expressed as (%). Normally distributed continuous data were tested with the *t*-test and expressed as ($\bar{x} \pm s$). The variables with significant differences selected in this study were tested for multicollinearity, with variance inflation factors (VIF) <5, and no interactions were observed. Risk factors for post-CRS UTIs in ovarian cancer patients were analyzed using logistic regression. R software (R software version 3.6.3 and the rms package) was used to construct the nomogram model. The ROC curve was plotted to evaluate the discrimination of the nomogram for urinary tract infection after CRS in ovarian cancer patients., and the decision curve analysis (DCA) was used to assess its clinical application value. A P<0.05 was considered statistically significant.

Results

Comparison of Clinical Data Between the Modeling Group and Validation Group

There were no differences in clinical data such as age, BMI, hypertension, diabetes, tumor stage, operative time, intraoperative blood loss, length of hospital stay, number of catheterizations, indwelling catheter duration, postoperative hypoproteinemia, prophylactic use of antibiotics, preoperative chemotherapy, and urinary tract infection prevention education between the modeling group and the validation group (P>0.05). See Table 1.

Table 1 Comparison of Clinical Data Between the Modelling Group and the Verification Group

Factor	Modelling Group (n=244)	Validation Group (n=105)	χ^2	*P*
Age (years)			0.118	0.731
<65	135 (55.33)	56 (53.33)		
≥65	109 (44.67)	49 (46.67)		
BMI (kg/m^2)			0.089	0.765
<24	139 (56.97)	58 (55.24)		
≥24	105 (43.03)	47 (44.76)		

(*Continued*)

Table 1 (Continued).

Factor	Modelling Group (n=244)	Validation Group (n=105)	χ^2	*P*
Hypertension			0.076	0.783
Yes	78 (31.97)	32 (30.48)		
No	166 (68.03)	73 (69.52)		
Diabetes			0.275	0.600
Yes	112 (45.90)	45 (42.86)		
No	132 (54.10)	60 (57.14)		
Tumour staging			0.206	0.650
III stage	111 (45.49)	45 (42.86)		
IVA stage	133 (54.51)	60 (57.14)		
Surgical time (h)			0.771	0.380
<4	110 (45.08)	42 (40.00)		
≥4	134 (54.92)	63 (60.00)		
Intraoperative blood loss (mL)			0.024	0.878
<500	130 (53.28)	55 (52.38)		
≥500	114 (46.72)	50 (47.62)		
Length of hospitalisation (d)			0.206	0.650
<10	111 (45.49)	45 (42.86)		
≥10	133 (54.51)	60 (57.14)		
Number of catheterizations (times)			0.326	0.568
1	122 (50.00)	56 (53.33)		
>1	122 (50.00)	49 (46.67)		
Catheter retention time (d)			0.231	0.631
<7	130 (53.28)	53 (50.48)		
≥7	114 (46.72)	52 (49.52)		
Postoperative hypoproteinemia			0.072	0.788
Yes	92 (37.70)	38 (36.19)		
No	152 (62.30)	67 (63.81)		
Prophylactic use of antimicrobials			0.172	0.678
Yes	68 (27.87)	27 (25.71)		
No	176 (72.13)	78 (74.29)		
Preoperative chemotherapy			0.308	0.579
Yes	77 (31.56)	30 (28.57)		
No	167 (68.44)	75 (71.43)		
Urinary tract infection Prevention campaign			0.421	0.517
Acceptance	137 (56.15)	55 (52.38)		
Deficiencies	107 (43.85)	50 (47.62)		

Abbreviations: d, days; h, hours; mL, milliliters.

Comparison of Clinical Data Between the Infection and Non-Infection Groups

Among 349 patients, 86 experienced infections, with an incidence rate of 24.64%. In the modeling group, 61 out of 244 patients experienced infections, with an incidence rate of 25.00%. Differences were observed between the two groups in terms of age, diabetes, tumor staging, number of catheterizations, duration of catheter retention, and postoperative hypoproteinemia (P<0.05). No differences were observed for other clinical data (P>0.05). See Table 2.

Analysis of Risk Factors for Post-CRS Urinary Tract Infections in Ovarian Cancer Patients

Whether a urinary tract infection occurred post-CRS in ovarian cancer patients was taken as the dependent variable (yes = 1, no = 0). Factors with differences in Table 2 were included as independent variables. Variable assignment methods are detailed

Table 2 Comparison of Clinical Data Between Infected and Non-Infected Groups

Factor	Infected Group (n=61)	Non-Infected Group (n=183)	χ^2	*P*
Age (years)			14.376	**<0.001**
<65	21 (34.43)	114 (62.30)		
≥65	40 (65.57)	69 (37.70)		
BMI (kg/m^2)			0.451	0.502
<24	37 (60.66)	102 (55.74)		
≥24	24 (39.34)	81 (44.26)		
Hypertension			0.025	0.874
Yes	20 (32.79)	58 (31.69)		
No	41 (67.21)	125 (68.31)		
Diabetes			12.675	**<0.001**
Yes	40 (65.57)	72 (39.34)		
No	21 (34.43)	111 (60.66)		
Tumour staging			21.866	**<0.001**
III stage	12 (19.67)	99 (54.10)		
IVA stage	49 (80.33)	84 (45.90)		
Surgical time (h)			1.788	0.181
<4	23 (37.70)	87 (47.54)		
≥4	38 (62.30)	96 (52.46)		
Intraoperative blood loss (mL)			3.148	0.076
<500	24 (39.34)	96 (52.46)		
≥500	37 (60.66)	87 (47.54)		
Length of hospitalisation (d)			0.270	0.603
<10	26 (42.62)	85 (46.45)		
≥10	35 (57.38)	98 (53.55)		
Number of catheterizations (times)			13.661	**<0.001**
1	18 (29.51)	104 (56.83)		
>1	43 (70.49)	79 (43.17)		
Catheter retention time (d)			13.720	**<0.001**
<7	20 (32.79)	110 (60.11)		
≥7	41 (67.21)	73 (38.39)		
Postoperative hypoproteinemia			26.894	**<0.001**
Yes	40 (65.57)	52 (28.42)		
No	21 (34.43)	131 (71.58)		
Prophylactic use of antimicrobials			0.109	0.742
Yes	16 (26.23)	52 (28.42)		
No	45 (73.77)	131 (71.58)		
Preoperative chemotherapy			0.158	0.691
Yes	18 (29.51)	59 (32.24)		
No	43 (70.49)	124 (67.76)		
Urinary tract infection Prevention campaign			0.050	0.823
Acceptance	35 (57.38)	102 (55.74)		
Deficiencies	26 (42.62)	81 (44.26)		

Note: Bold values indicate statistical significance (P < 0.05).
Abbreviations: d, days; h, hours; mL, milliliters.

in Table 3. Multivariate logistic regression analysis (Forward stepwise method, with entry criterion α = 0.05 and removal criterion α = 0.10) identified age, diabetes, tumor staging, number of catheterizations, duration of catheter retention, and postoperative hypoproteinemia as risk factors for urinary tract infections after CRS in ovarian cancer patients (P<0.05). See Table 4.

Table 3 Assignment Methods of Argument Variables

Variable	Assignment Method
Age	<65 years old=0, ≥65 years old=1
Diabetes	Yes=1, no=0
Tumour staging	III stage=0, IVA stage=1
Number of catheterizations	>1 time=1, 1time=0
Catheter retention time	≥7 d=1, <7 d=0
Postoperative hypoproteinemia	Yes=1, no=0

Table 4 Analysis of Factors Affecting Urinary Tract Infection After CRS in Patients with Ovarian Cancer

Variable	β value	SE Variable	Wald χ^2 Variable	*P* Variable	OR Variable	95% CI
Age	2.290	0.522	19.226	<0.001	9.878	3.549~27.497
Diabetes	1.872	0.520	12.931	<0.001	6.498	2.343~18.023
Tumour staging	1.695	0.515	10.841	<0.001	5.449	1.986~14.948
Number of catheterizations	2.093	0.492	18.093	<0.001	8.112	3.092~21.285
Catheter retention time	1.310	0.506	6.692	0.010	3.706	1.374~9.999
Postoperative hypoproteinemia	1.336	0.507	6.954	0.008	3.805	1.409~10.273
Constant	−5.550	0.693	64.187	<0.001	0.004	–

Development of a Nomogram Model for Predicting Post-CRS Urinary Tract Infections in Ovarian Cancer Patients

A nomogram model was constructed based on the risk factors identified by Logistic regression analysis, with $P = e^x / (1 + e^x)$, where x = −5.550 + 2.290 × age + 1.872 × diabetes + 1.695 × tumor stage + 2.093 × number of catheterizations + 1.310 × indwelling catheter duration + 1.3363 × postoperative hypoproteinemia. Risk factors were assigned scores in order of their influence: age, number of catheterizations, diabetes, tumor staging, postoperative hypoproteinemia, and duration of catheter retention. For example, a patient aged <65 years (0 points), with diabetes (81.5 points), tumor staging IVA (73.5 points), catheterized more than once (92.0 points), catheter retention duration >7 days (58.5 points), and no postoperative hypoproteinemia (0 points) would have a total score of 305.5 points. Drawing a perpendicular line at this total score indicates a predicted value of 79%. See Figure 2.

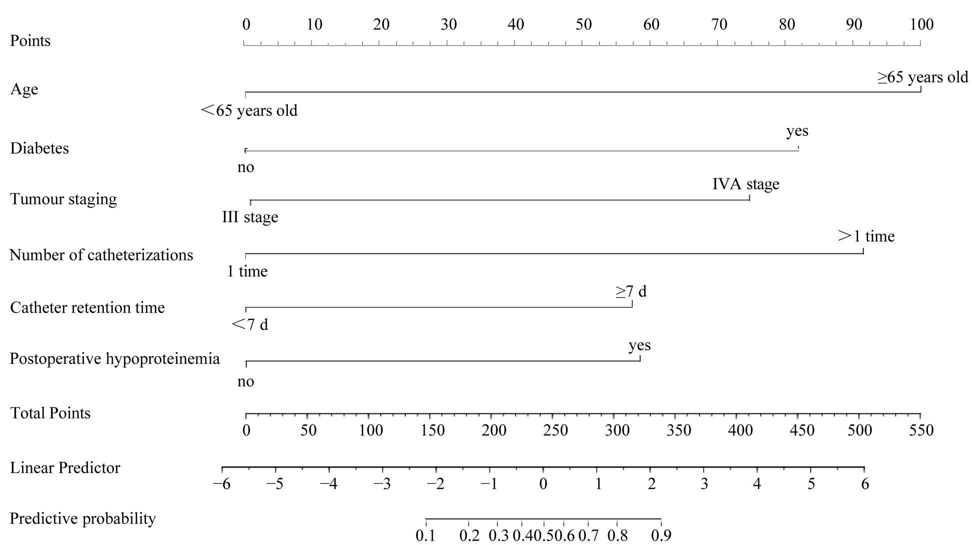

Figure 2 Construction of a nomogram model of urinary tract infection after CRS in ovarian cancer patients.

Nomogram Model in the Modeling Group

The AUC of the nomogram model in the modeling group was 0.950 (95% CI: 0.917–0.983), and after 1000 bootstrap resamplings, the H-L test result was χ^2=6.912, P=0.697. See Figure 3.

Nomogram Model in the Validation Group

The AUC of the nomogram model in the validation group was 0.970 (95% CI: 0.942–0.998), and after 1000 bootstrap resamplings, the H-L test result was χ^2=6.756, P=0.642. See Figure 4.

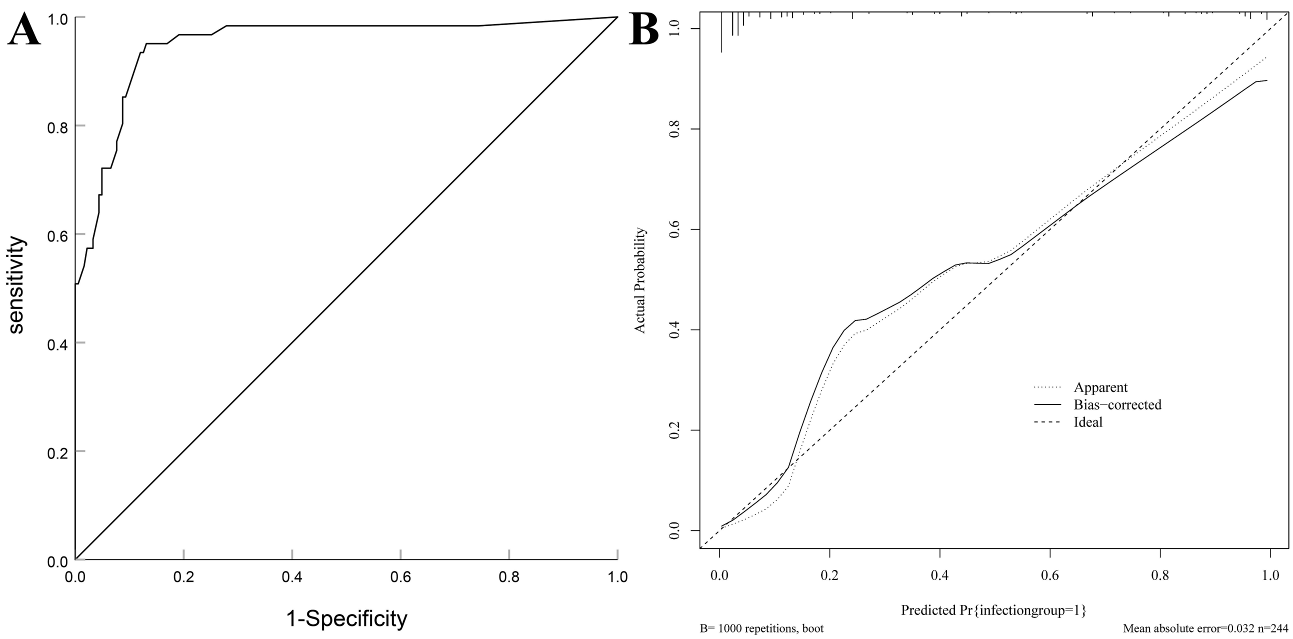

Figure 3 Model the group nomogram model. (**A**) ROC curve for modeling group; (**B**) Modeling group calibration curves.
Notes: Apparent refers to the prediction curve; bias corrected refers to the bias-corrected curve; ideal refers to the ideal curve.

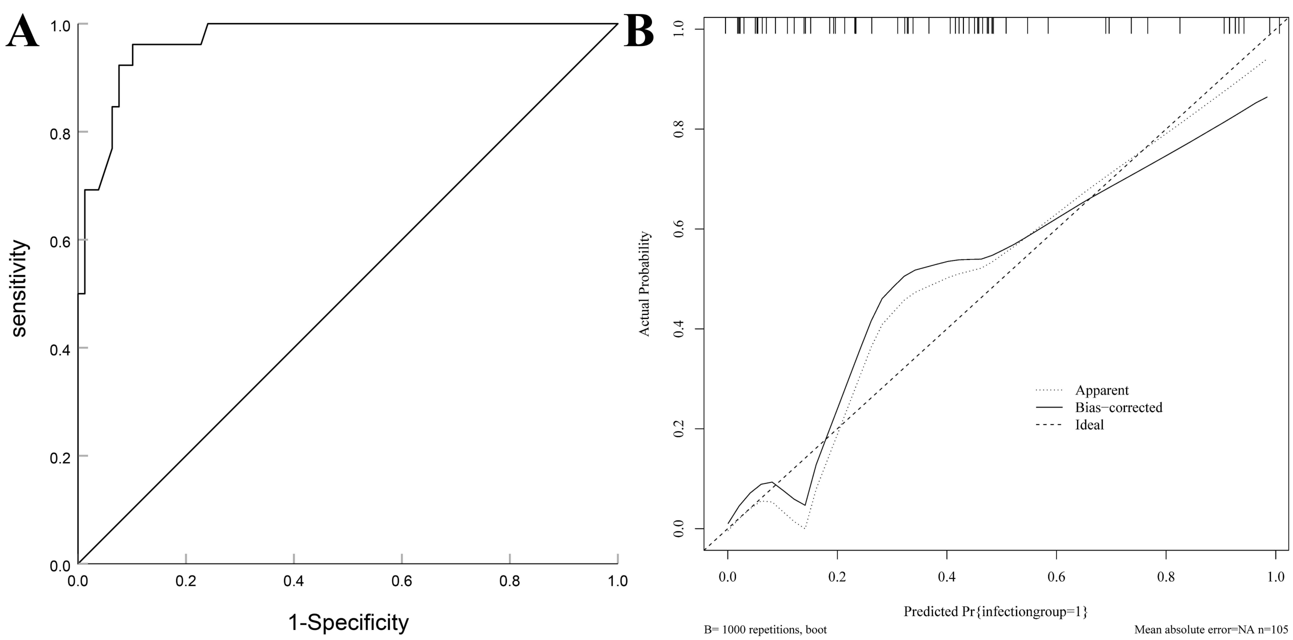

Figure 4 Validation of the group nomogram model. (**A**) ROC curve for the validation group; (**B**) Calibration curve for the validation group.
Notes: Apparent refers to the prediction curve; bias corrected refers to the bias-corrected curve; ideal refers to the ideal curve.

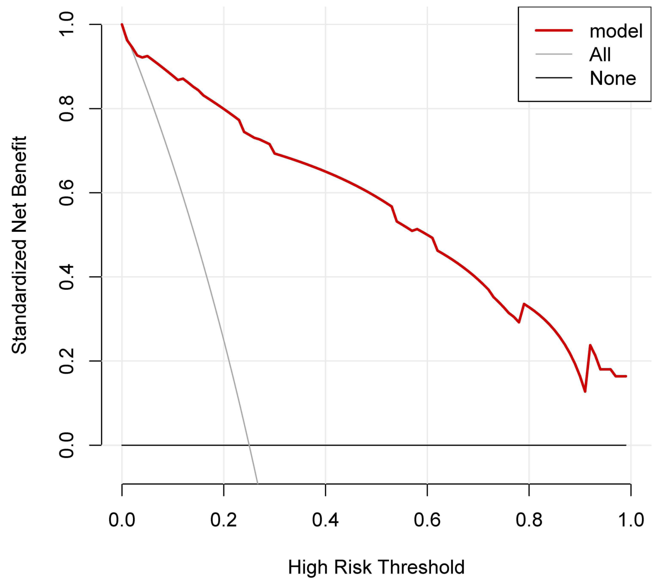

Figure 5 Decision curve analysis (DCA) of the nomogram.
Notes: "model" refers to the DCA mo "All" indicates that the entire population is intervened, "None" means no intervention at all, and the net benefit remains 0.

DCA Curve of the Nomogram Model

The DCA curve indicates that when the probability ranges from 0.08 to 0.90 (within the typical 0 to 1 range), the nomogram model demonstrates high clinical utility for evaluating post-CRS urinary tract infections in ovarian cancer patients, significantly enhancing net benefit and providing clinicians with clear guidance on the model's applicable scenarios. See Figure 5.

Discussion

Ovarian cancer primarily affects postmenopausal women and is a common malignant tumor of the female reproductive system, posing a significant threat to women's health.[13] Due to its often-subtle early symptoms, ovarian cancer is often diagnosed at an advanced stage. In clinical treatment of late-stage patients, CRS is the primary approach, enabling resection of lesions and extending patient survival. However, the complexity of CRS often leads to complications such as postoperative urinary tract infections (UTIs), adversely affecting patient recovery.[13,14] This study found that in the modeling group, 61 out of 244 patients experienced infections, with an incidence rate of 25.00%, which was relatively high and similar to previous studies.[15] Therefore, constructing a risk prediction model is crucial for clinical prevention.

This study identified six influencing factors (age, diabetes, tumor staging, number of catheterizations, duration of catheter retention, and postoperative hypoproteinemia) and analyzed their causes: (1) Age: For older patients, advancing age leads to degenerative changes in organs, reduced immune function, and impaired metabolic processes, weakening the urethral mucosal barrier. When pathogens invade, the body struggles to resist, thereby increasing infection risk.[16,17] (2) Diabetes: Diabetic patients often have complications, particularly diabetic nephropathy, which increases the risk of UTIs. High blood glucose levels provide an optimal environment for pathogen growth, facilitating UTIs when pathogens invade the urinary system. Additionally, comorbidities affect immune function, creating conditions for pathogen proliferation and increasing infection risk.[17–19] (3) Tumor staging: Advanced tumor staging increases tumor burden, further weakening immune function and increasing susceptibility to infections.[16] (4) Catheterization and retention duration: The urethral mucosa has natural antibacterial properties, and urination flushes the urethra, reducing pathogen invasion and colonization. However, repeated catheterizations can damage the urethral mucosa, and prolonged catheter retention increases opportunities for pathogen invasion, compromising the urethral immune barrier. Pathogens can also enter the body through the catheter, and longer retention times further heighten infection risk.[20,21] Strict control of catheter retention indications, adherence to standardized catheterization protocols, and attention to catheter patency and sealing are essential to reduce UTI risk. (5) Postoperative hypoproteinemia: This common complication after major surgery is associated with surgical trauma and stress. Hypoproteinemia exacerbates inflammatory stress and disrupts immune function. Combined with catheter use, urethral damage significantly increases bacterial and fungal infections, heightening the risk of UTIs.[22,23] Early postoperative nutritional support, active management of negative nitrogen balance caused by surgery, and prevention of malnutrition can help reduce hypoproteinemia. Prophylactic use of antibiotics and urinary tract infection prevention education are also factors affecting postoperative urinary tract infection; however, no significant differences were observed in this study, which may be related to the relatively small sample size. In this study, the OR values for age and the number of urinary catheterizations were relatively high, which may also be associated with the sample distribution.

The nomogram model constructed in this study yielded AUC values of 0.950 and 0.970 for the modeling and validation groups, respectively. The H-L test indicated good fit, with no significant differences between predicted and actual values, demonstrating strong predictive discrimination. Additionally, the DCA curve showed high clinical utility of the nomogram for probabilities ranging from 0.08 to 0.90. Studies have found that a nomogram model constructed based on risk factors for urinary tract infections after radiotherapy in cervical cancer patients demonstrates good accuracy and consistency, with decision curve analysis showing improved net benefit when the probability ranges from 0.1 to 0.9.[24] Similar to the findings of this study, this indicates that constructing nomogram models can effectively assist clinicians in preventing infections based on influencing factors, thereby reducing infection risk and improving patients' quality of life.

This study has certain limitations. The small sample size may not represent the entire patient population, and being a single-center retrospective study increases the risk of bias. Additionally, regional differences and hospital practice patterns may also affect the results, and the lack of external validation is another limitation. In fact, beyond the factors analyzed in this study, many other factors—such as ascites volume, surgical scope, antibiotic use, and surgical complexity—may influence urinary tract infections. These factors should be further investigated in future studies with larger sample sizes and multicenter prospective designs for validation.

Conclusion

The nomogram model constructed based on the identified risk factors demonstrated good discrimination and calibration in predicting the risk of urinary tract infection after CRS in patients. However, this model remains in the preliminary stage and requires external and multicenter validation before it can be applied in clinical practice.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics

This study involving human participants was in accordance with the ethical standards of the Medical Ethics Committee of Meizhou People's Hospital (2022-C-46) and with the 1964 Helsinki Declaration. Written informed consent to participate in this study was provided by the participants.

Disclosure

The authors declare that they have no conflicts of interest.

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