

Risk Factors of Catheter-Associated Urinary Tract Infections Following Radical Hysterectomy for Cervical Cancer: A Propensity Score Matching-Based Study

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Purpose: This study aims to examine the risk factors for catheter-associated urinary tract infection (CAUTI) following radical hysterectomy for cervical cancer (CC). Furthermore, the study seeks to develop a visual model that can effectively assist physicians in improving their proficiency in diagnosing, treating, and preventing CAUTIs.

Patients and Methods: 48 subjects who developed CAUTI postoperatively were assigned to the infection group. There were 443 cases who did not develop CAUTI, and a 1:1 propensity score matching (PSM) method was employed to match 48 cases for the non-infection group. Univariate logistic and multivariate stepwise regression analyses were used to analyze the risk factors for CAUTI following radical hysterectomy for CC. Subsequently, a nomogram-based model was developed, and its effectiveness was comprehensively assessed.

Results: The incidence rate of CAUTI in 491 patients who underwent radical hysterectomy for CC was 9.76% (48/491). Multivariate stepwise regression analysis revealed that the duration of urinary catheterization, urinary leukocyte esterase, and positive urine culture were the independent risk factors for CAUTI after radical hysterectomy for CC (all $\beta > 0$, $P < 0.05$). A nomogram model incorporating these independent risk factors was constructed, and receiver operating characteristic (ROC) and decision curve analysis (DCA) curves were generated. The ROC curve exhibited an area under the curve value of 0.9035, 95% CI of 0.8352–0.9718, specificity of 0.8214, sensitivity of 0.8571, accuracy of 0.8429, positive predictive value of 0.8780, and negative predictive value of 0.7931.

Conclusion: The duration of urinary catheterization, urinary leukocyte esterase, and positive urine culture are independent risk factors for CAUTI after radical hysterectomy for CC. This nomogram-based model exhibits numerous advantages, including simplicity, user-friendliness, high diagnostic accuracy, and significant clinical value, which can provide assistance in early clinical diagnosis decision-making.

Keywords: risk factors, hysterectomy, uterine cervical neoplasms, urinary tract infections, propensity score

Introduction

Cervical cancer (CC) is among the top three malignant tumors affecting women on a global scale. According to the Global Cancer Observatory (GLOBOCAN) statistics 2020,¹ there were approximately 604,000 new cases of and 342,000 deaths from CC worldwide. In China, CC is one of the most common gynecologic malignancies, with the second highest incidence among female malignancies in China, only after breast cancer.² Approximately 110,000 new cases and 59,000

deaths were reported, corresponding to 18.2% and 17.3% of the global incidence and mortality rates, respectively.³ In addition, compelling evidence suggests a noticeable tendency towards diagnoses occurring at younger ages.⁴

Radical hysterectomy is the primary treatment modality for early-stage CC.⁵ Radical hysterectomy can notably facilitate patient survival rate; however, the procedure involves extensive surgical scope and requires concomitant lymph node dissection, resulting in significant surgical trauma. Surgical resection involves a broad extent, and extensive pelvic dissection can lead to the disruption of the autonomic innervation of the bladder, which is formed by the pelvic visceral nerves and inferior hypogastric plexus. This disruption can result in acute and chronic voiding dysfunction, thus increasing the risk of neurogenic bladder dysfunction and urinary retention.⁶ Postoperatively, patients may experience bladder paralysis and detrusor dysfunction, leading to involuntary voiding. Hence, urinary catheterization is the standard postoperative management for these patients.^{7–10} However, urethral mucosa damage is common in patients with long-term indwelling urinary catheterization, which compromises their natural defense barrier and substantially increases the risk of developing urinary tract infections (UTIs).⁷

Catheter-associated UTI (CAUTI) has been identified as the most common nosocomial infection following surgical procedures for gynecologic malignancies.^{11,12} International studies have reported rates ranging between 4.8% and 19%,^{9,13,14} while domestic research in China has reported rates between 12.9% and 24.69%.^{15,16} In the present study, the incidence rate of CAUTI after radical hysterectomy for CC was 9.76% (48/491), indicating a high infection rate that warrants attention. CAUTI is predominantly caused by bacterial infections and manifests such symptoms or signs as fever, dysuria, and suprapubic tenderness. Although the clinical presentation in most patients is insignificant, the condition can worsen and lead to bacteremia, systemic infection, or even life-threatening complications if left untreated. These infections not only impact the patients' postoperative healing process but also increase their mental and economic burden, resulting in prolonged hospital stays and increased healthcare costs.^{11,17,18} Therefore, it is necessary to conduct risk assessments, identify risk factors, develop effective models, and implement early detection and timely interventions for CAUTI following radical hysterectomy for CC.¹⁹

This study aimed to explore the risk factors for CAUTI after radical hysterectomy for CC and establish a nomogram-based model to improve their prevention and early diagnosis in clinical settings.

Materials and Methods

Patient Information

Data of 949 inpatients diagnosed with cervical cancer who were admitted to the First Affiliated Hospital of Nanjing Medical University (a Grade-A tertiary hospital with 4500 beds) between January 2017 and December 2020 were systematically and consecutively collected from the Xinglin Hospital Infection Real-time Monitoring System. This study has been approved by the Ethics Committee of the First Affiliated Hospital of Nanjing Medical University.

Inclusion and Exclusion Criteria

A total of 491 patients who did underwent radical hysterectomy were included and 458 patients who did not underwent radical hysterectomy were excluded. Finally, a total of 48 individuals who developed CAUTI postoperatively were assigned to the infection group. There were 443 individuals who did not develop CAUTI, and a 1:1 propensity score matching (PSM) method was used to match 48 cases to form the non-infection group (Figure 1).

Inclusion of Variables

The outcome variable (Y) was defined as the occurrence of CAUTI after radical hysterectomy for CC. Based on a review of relevant literature^{2,5,6} and clinical considerations, the following risk factor variables (X) were identified: (1) patient demographics, including age, diabetes, hypertension, and coronary heart disease (CHD); (2) preoperative factors, such as preoperative blood glucose, serum albumin, chemoradiotherapy, use of immunosuppressant drugs, and antimicrobial prophylaxis; (3) intraoperative factors, including surgical approach, intraoperative blood loss, and duration of surgery; (4) postoperative factors, such as postoperative serum albumin, onset of fever, duration of continuous fever, fever peak, total number of postoperative fever days, urinary tract irritation symptoms, urinary white blood cell (U-WBC) count, urinary

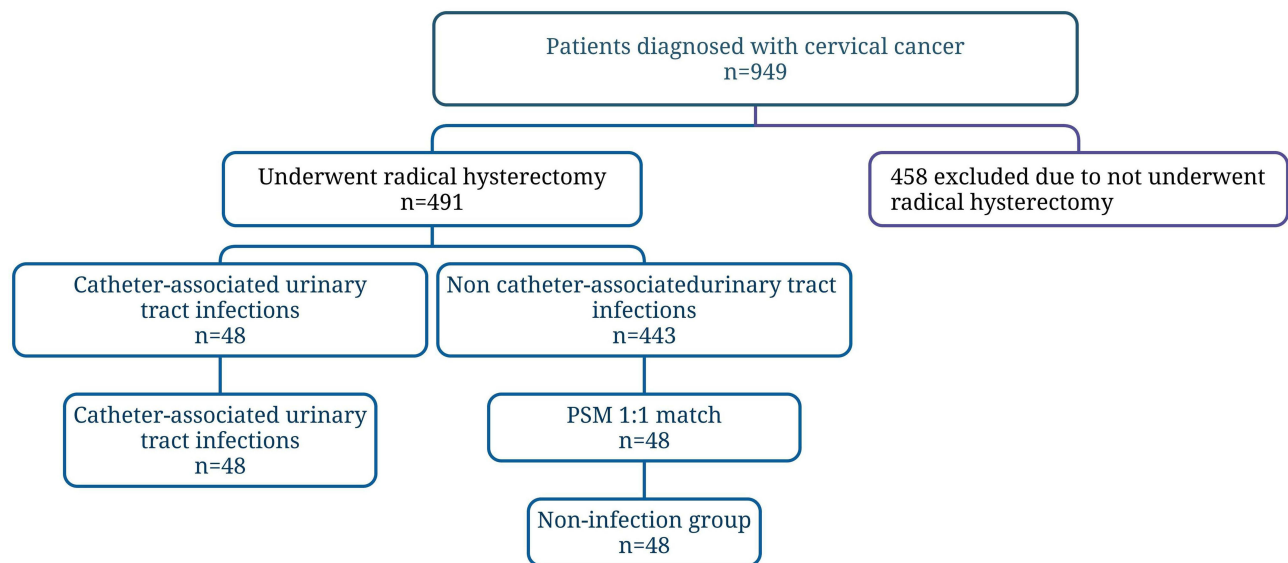


Figure 1 Flow diagram for patient screening.
Abbreviations: PSM, propensity score matching.

red blood cell count, urine nitrite, urinary leukocyte esterase, number of catheter insertions, duration of urinary catheterization, positive urine culture, and presence of *Escherichia coli* and *Klebsiella pneumoniae* in urine culture.

PSM

To reduce selection bias and achieve covariate balance between our study groups, we implemented Propensity Score Matching (PSM) using the MatchIt package in RStudio. We employed a 1:1 matching ratio with a caliper width of 0.01, taking into account key baseline variables such as age, diabetes status, hypertension, and coronary heart disease (CHD). The MatchIt package facilitated the creation of a well-balanced cohort, ensuring that our subsequent analyses would be more robust and reliable.

Diagnostic Criteria

The diagnostic criteria for UTI were based on the Hospital Infection Diagnostic Criteria (Trial) issued by the former Ministry of Health in 2001.²⁰ CAUTI was defined as UTI diagnosed within 48 h after catheterization or removal of the catheter.³

Statistical Analysis

Categorical data were presented as proportions (%) and analyzed using the Chi-square test or Fisher's exact probability test. Continuous data were presented as mean $\pm$ standard deviation or median (P25-P75). Intergroup comparisons for normally distributed continuous data were conducted using *t*-test, while those for skewed distributed continuous data were conducted using the Mann-Whitney *U*-test. Logistic regression analysis was utilized to examine the risk factors for CAUTI in patients undergoing radical hysterectomy for CC. Significant variables identified through univariate analysis were subsequently incorporated into a multivariate stepwise regression analysis to screen out independent risk factors. Using these factors, we attempted to construct a nomogram model, which serves as a reference for subsequent related research. Furthermore, receiver operating characteristic (ROC) curves were generated to evaluate the predictive performance and clinical decision value of the model, using metrics such as area under the curve (AUC), sensitivity, specificity, accuracy, and decision curve analysis (DCA) curves. An AUC closer to 1 indicates a better diagnostic performance. AUC values >0.9 indicate high accuracy, values between 0.7 and 0.9 suggest moderate accuracy, and values falling to 0.5–0.7 indicate low accuracy.²¹ The net benefit of the model was evaluated using DCA to assess its clinical application value. The data was organized, entered, and cleaned using WPS 2019 software. Statistical analysis was conducted using Statistical Product and Service Solutions (SPSS), version 25.0 (IBM Corp., Armonk, NY, USA),

RStudio(<http://www.R-project.org>, R Foundation), and EmpowerStats (<http://www.empowerstats.com>, X&Y Solutions Inc., Boston, MA, USA). Odds ratios (OR) and 95% CI were calculated. A P-value<0.05 (two-sided) was considered to represent statistical significance.

Results

Distribution of Population Characteristics Before and After PSM in the Infection and Non-Infection Groups

The incidence of CAUTI was 9.76% (48/491) in 491 patients who underwent radical hysterectomy for CC. Before PSM, a significant difference was noted between the infection and non-infection groups in terms of diabetes ($P = 0.007$). After PSM, no significant differences were observed between both groups in terms of age, diabetes, hypertension, and CHD (all $P > 0.05$; Table 1).

Univariate Analysis of CAUTI Occurrence Following Radical Hysterectomy for CC After PSM

After balancing the demographic variables between the two groups through PSM, a univariate analysis was conducted on other variables in both groups. The univariate analysis identified U-WBC count (odds ratio [OR] = 1.00, 95% confidence interval [CI]: 1.00–1.01; $P = 0.020$), urine nitrite 2+ (OR = 6.30, 95% CI: 2.17–18.30; $P = 0.001$), urinary leukocyte esterase 1+ (OR = 6.30, 95% CI: 2.17–18.30; $P = 0.001$), urinary leukocyte esterase 3+ (OR = 21.87, 95% CI: 5.44–87.90; $P < 0.001$), number of catheter insertions ≥ 2 (OR = 3.54, 95% CI: 1.16–10.81; $P = 0.026$), duration of urinary catheterization (OR = 1.49, 95% CI: 1.26–1.77; $P < 0.001$), and positive urine culture (OR = 53.08, 95% CI: 6.40–440.34; $P = 0.002$) as the risk factors for CAUTI occurrence after radical hysterectomy for CC (Table 2).

Table 1 Distribution of Population Characteristics Before and After PSM Between the Infection and Non-Infection Groups

Variable	Before PSM			Statistical Value	P	After PSM			Statistical Value	P
	All (n = 491)	Infection Group (n = 48)	Non-Infection Group (n = 443)			All (n = 96)	Infection Group (n = 48)	Non-Infection Group (n = 48)		
Age (year)	47.13 ± 9.08	46.00 ± 8.33	47.25 ± 9.16	0.906	0.365	46.01 ± 8.58	46.00 ± 8.33	46.02 ± 8.91	0.012	0.991
Diabetes				5.468	0.019				1.227	0.268
Yes	468 (95.32)	42 (87.50)	426 (96.16)			88 (91.67)	42 (87.50)	46 (95.83)		
No	23 (4.68)	6(12.50)	17 (3.84)			8(8.33)	6(12.50)	2(4.17)		
Hypertension				3.101	0.078				/	>0.999
Yes	432 (87.98)	46 (95.83)	386 (87.13)			92 (95.83)	46 (95.83)	46 (95.83)		
No	59 (12.02)	2(4.17)	57 (12.02)			4(4.17)	2(4.17)	2(4.17)		
CHD				0.658	>0.999*				/	>0.999
Yes	485 (98.78)	48 (100.00)	437 (98.65)			96 (100.00)	48 (100.00)	48 (100.00)		
No	6 (1.22)	0(0)	6 (1.35)			0 (0)	0 (0)	0 (0)		

Note: * represents the use of Fisher's exact probability method.
Abbreviations: PSM, propensity score matching; CHD, coronary heart disease.

Table 2 Univariate Analysis of CAUTI Occurrence After Radical Hysterectomy for CC After PSM

Variable	All (n = 96)	Infection Group (n = 48)	Non-Infection Group (n = 48)	OR	95% CI	P
Preoperative factors						
Preoperative blood glucose	4.810 (4.490, 5.340)	4.840 (4.490, 5.330)	4.790 (4.490, 5.340)	1.20	0.86, 1.69	0.288
Preoperative serum albumin	39.797 ± 3.726	39.554 ± 3.899	40.040 ± 3.570	0.97	0.87, 1.08	0.522
Chemoradiotherapy						
Yes	92 (95.833)	45 (93.750)	47 (97.917)	1		
No	4 (4.167)	3 (6.250)	1 (2.083)	3.13	0.31, 31.25	0.330
Immunosuppressant drug						
Yes	95 (98.958)	48 (100.000)	47 (97.917)	1		
No	1 (1.042)	0 (0.000)	1 (2.083)	0	0.00, –	0.992
Antimicrobial prophylaxis						
Yes	33 (34.375)	15 (31.250)	18 (37.500)	1		
No	63 (65.625)	33 (68.750)	30 (62.500)	1.32	0.57, 3.07	0.520
Intraoperative factors						
Surgical approach						
Laparoscopy	50 (52.083)	28 (58.333)	22 (45.833)			
Laparotomy	46 (47.917)	20 (41.667)	26 (54.167)	0.6	0.27, 1.35	0.222
Intraoperative blood loss	390.104 ± 367.110	345.833 ± 270.310	434.375 ± 441.968	1.00	1.00, 1.00	0.245
Duration of surgery (h)	3.954 ± 1.020	4.141 ± 1.200	3.767 ± 0.769	1.46	0.96, 2.21	0.076
Postoperative factors						
Postoperative serum albumin	31.351 ± 2.738	31.152 ± 2.652	31.559 ± 2.810	0.95	0.81, 1.10	0.482
Fever occurrence						
Yes	47 (48.958)	20 (41.667)	27 (56.250)	1		
No	49 (51.042)	28 (58.333)	21 (43.750)	1.80	0.80, 4.04	0.154
Duration of continuous fever	1.156 ± 1.578	1.458 ± 1.810	0.854 ± 1.255	1.31	0.98, 1.75	0.069
Total days of postoperative fever	1.354 ± 1.841	1.688 ± 2.002	1.021 ± 1.618	1.24	0.97, 1.57	0.083
Fever peak	38.538 ± 0.383	38.561 ± 0.389	38.505 ± 0.373	1.47	0.32, 6.71	0.621
Urinary tract irritation symptoms						
Yes	93 (96.875)	45 (93.750)	48 (100.000)	1		
No	3 (3.125)	3 (6.250)	0 (0.000)	/	/	0.990

(Continued)

Table 2 (Continued).

Variable	All (n = 96)	Infection Group (n = 48)	Non-Infection Group (n = 48)	OR	95% CI	P
U-WBC	191.346 ± 379.419	318.914 ± 459.581	77.067 ± 236.792	1.00	1.00, 1.01	0.020
U-RBC	579.652 ± 4002.722	1059.926 ± 5773.498	149.406 ± 349.025	1.00	1.00, 1.00	0.653
Urine nitrite						
Negative	62 (68.132)	20 (46.512)	42 (87.500)	1		
1+	5 (5.495)	5 (11.628)	0 (0)	/	/	0.992
2+	24 (26.374)	18 (41.860)	6 (12.500)	6.30	2.17, 18.30	0.001
Urinary leukocyte esterase						
Negative	31 (34.444)	6 (13.953)	25 (53.191)	1		
±	12 (13.333)	6 (13.953)	6 (12.766)	4.17	0.99, 17.59	0.052
1+	8 (8.889)	5 (11.628)	3 (6.383)	6.94	1.29, 37.49	0.024
2+	14 (15.556)	5 (11.628)	9 (19.149)	2.31	0.56, 9.48	0.243
3+	25 (27.778)	21 (48.837)	4 (8.511)	21.87	5.44, 87.99	<0.001
Number of catheter insertions						
1	77 (80.208)	34 (70.833)	43 (89.583)	1		
>1	19 (19.792)	14 (29.17)	5 (10.42)	3.54	1.16, 10.81	0.026
During of urinary catheterization (day)	12.708 ± 4.498	14.958 ± 4.851	10.458 ± 2.649	1.49	1.26, 1.77	<0.001
Urine culture results						
Negative	16 (21.333)	1 (2.128)	15 (53.571)	1		
Positive	59 (78.667)	46 (97.872)	13 (46.429)	53.08	6.40, 440.34	0.002
Urine culture for Escherichia coli						
Yes	13 (22.034)	11 (23.913)	2 (15.385)	1		
No	46 (77.966)	35 (76.087)	11 (84.615)	0.58	0.11, 3.02	0.516
Urine culture for Klebsiella pneumoniae						
Yes	50 (84.746)	39 (84.783)	11 (84.615)	1		
No	9 (15.254)	7 (15.217)	2 (15.385)	0.99	0.18, 5.45	0.988

Abbreviations: CAUTI, catheter-associated urinary tract infection; CC, cervical cancer; PSM, propensity score matching; OR, odds ratio; CI, confidence interval; U-WBC, urinary white blood cell; U-RBC, urinary red blood cell.

Multivariable Stepwise Regression Analysis of CAUTI Occurrence Following Radical Hysterectomy for CC After PSM

A stepwise regression analysis was performed using variables demonstrating significant statistical differences in the univariate analysis (U-WBC count, urine nitrite, urinary leukocyte esterase, catheter insertion, duration of urinary catheterization, and urine culture results) as the independent variables and the occurrence of CAUTI after radical hysterectomy for CC as the dependent variable. The results revealed that the independent risk factors for CAUTI occurrence following radical hysterectomy for CC were the duration of catheterization, urinary leukocyte esterase, and positive urine culture (all $\beta > 0$, $P < 0.05$). Furthermore, the model demonstrated predictive effectiveness, as indicated by the F-test ($F = 20.172$, $P < 0.01$; Table 3).

Construction and Performance Evaluation of the Nomogram Model for CAUTI Diagnosis Following Radical Hysterectomy for CC

A nomogram model was created by incorporating the independent risk factors for CAUTI after radical hysterectomy for CC. The visual depiction of the model is shown in Figure 2. The ROC and DCA curves were generated to evaluate the predictive performance of the model. The ROC curve indicated an AUC of 0.9035, with a 95% CI of 0.8352–0.9718, specificity of 0.8214, sensitivity of 0.8571, accuracy of 0.8429, positive predictive value of 0.8780, and negative predictive value of 0.7931. The DCA curve demonstrated that the model had higher net benefits at all critical probability values, indicating its good predictive value. Specific details are shown in Figures 3 and 4.

Discussion

This study identified the duration of catheterization, urinary leukocyte esterase, and positive urine culture as independent risk factors for Catheter-Associated Urinary Tract Infections (CAUTI) following radical hysterectomy for Cervical Cancer (CC). A nomogram model was developed using multivariate analysis to predict the occurrence of CAUTI. The nomogram model created was simple, quantitative, and user-friendly, with an area under the ROC curve of 90.35%, indicating high diagnostic accuracy. The model's clinical net benefit was also significant, reflecting its performance and value. The study used Propensity Score Matching (PSM) to balance covariates between infection and non-infection groups, enhancing the comparability of the population. It is noteworthy that a significant difference in diabetes prevalence between the two groups was observed prior to Propensity Score Matching (PSM). However, this difference disappeared after PSM was applied, indicating that the matching process successfully increased the comparability of the two groups and enhanced the scientific rigor of our analysis. By accounting for confounding variables through PSM, we were able to better isolate the independent effects of various factors on the studied outcome. The disappearance of the diabetes difference after PSM suggests that, when other factors are controlled for, diabetes may not independently contribute to the risk in our study population. This finding underscores the importance of controlling for confounding in observational studies and demonstrates how PSM can improve the validity of such research.²²

Table 3 Multivariable Stepwise Regression Analysis of CAUTI Occurrence Following Radical Hysterectomy for CC After PSM

Variable	Regression Coefficient	SE	t	P	VIF
a constant (math.)	−0.244	0.14	−1.74	0.086	/
Duration of catheterization	0.024	0.011	2.25	0.028	1.211
Urinary leukocyte esterase	0.103	0.038	2.683	0.009	1.186
Whether urine culture is positive	0.496	0.116	4.288	<0.001	1.246
F	$F(3, 66) = 20.172, P < 0.001$				

Abbreviations: Dependent variable: CAUTI; CAUTI, catheter-associated urinary tract infection; CC, cervical cancer; PSM, propensity score matching; SE, standard error; VIF, variance inflation factor.

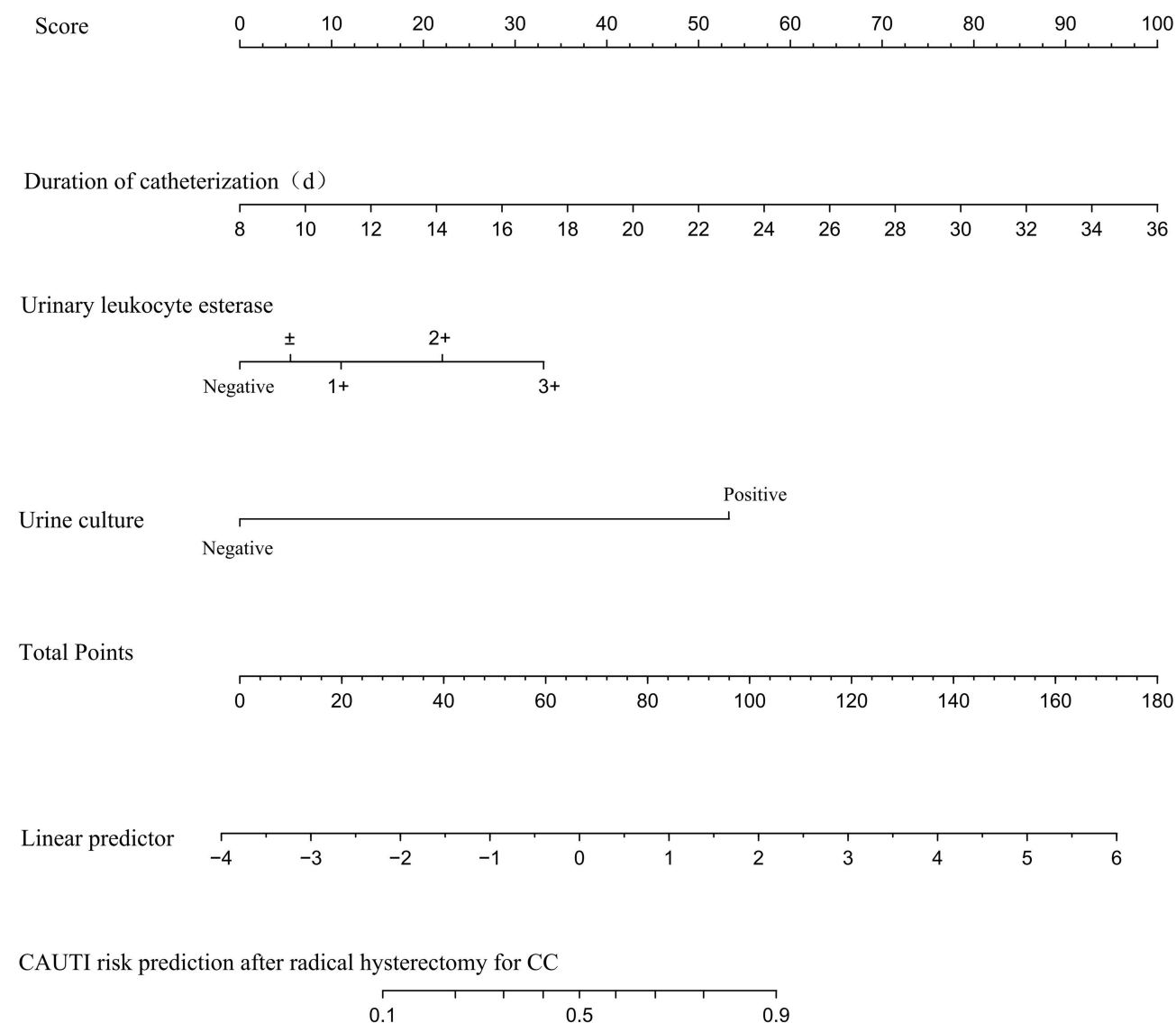


Figure 2 Nomogram model for predicting CAUTI occurrence after radical hysterectomy for CC.

Abbreviations: CAUTI, catheter-associated urinary tract infection; CC, cervical cancer.

It is worth noting that a previous study identified age ≥ 60 years, number of urinary catheter insertions ≥ 2 , duration of urinary catheterization ≥ 7 days, and comorbid diabetes as high-risk factors for CAUTI occurrence following radical hysterectomy for CC.²³ Our study identified the duration of urinary catheterization, urinary leukocyte esterase, and positive urine culture as the independent risk factors for CAUTI after radical hysterectomy for CC. The former study included a relatively small sample size of only 84 cases (with 18 infections), whereas this study enrolled a sample of 96 patients (with 48 infections). Furthermore, this study incorporated a comprehensive range of variables, including potential risk factors spanning preoperative, intraoperative, and postoperative stages. A greater number of confounding factors were also considered, resulting in a higher scientific integrity and validity of the research findings. Mercadel et al¹ have demonstrated that the duration of urinary catheterization exceeding 7 days is an independent risk factor, which is in line with our findings. This finding further emphasizes the importance of daily assessment of the necessity of indwelling urinary catheterization and highlights the need for early removal when clinically feasible to effectively reduce the incidence of CAUTI. A study²⁴ has also demonstrated that implementing a structured preoperative and postoperative bladder training program for patients can effectively enhance pelvic floor muscle function, mitigate spasms in the external urethral sphincter, and contribute to the amelioration of postoperative bladder dysfunction. This approach, to

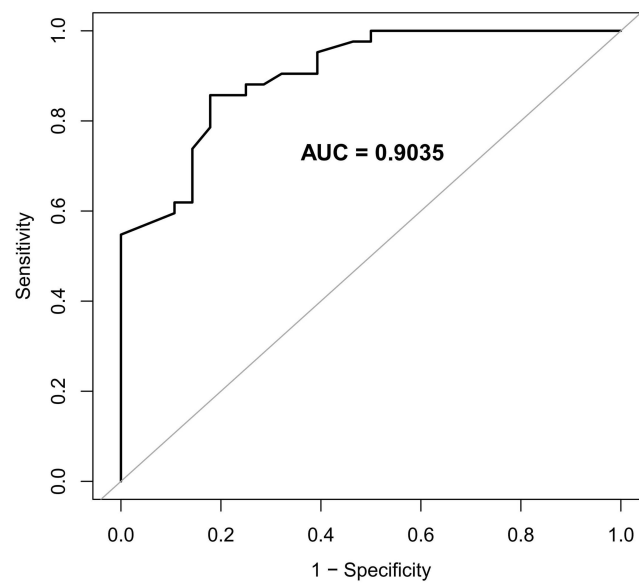


Figure 3 ROC curve of the model for CAUTI diagnosis after radical hysterectomy for CC.

Abbreviations: ROC, Receiver operating characteristic; CAUTI, catheter-associated urinary tract infection; CC, cervical cancer.

some extent, can decrease the time required for patients to regain control of their urinary elimination, thus diminishing the duration of indwelling catheterization and lowering the occurrence rate of CAUTI. To develop a model, we introduced urine routine and urine culture indicators innovatively. The inclusion of urinary leukocyte esterase testing, known for its high sensitivity and specificity, brings about a remarkable level of accuracy in UTI detection. This testing method plays a vital role in the early screening, diagnosis, and treatment of patients with UTIs, underscoring its considerable clinical significance.²⁵ In this study, urinary leukocyte esterase and positive urine culture were identified as the independent risk factors for CAUTI occurrence following radical hysterectomy for CC. The results are consistent with the prevailing clinical diagnosis and treatment practices in the field.²⁶

A nomogram model is developed based on multivariate analysis, which integrates multiple indicators to achieve individualized and precise probability prediction of a specific event. The existing body of studies on CAUTI following radical hysterectomy for CC is currently limited on both national and international levels, which mainly focus on pathogenic characteristics or analysis of risk factors.^{2,6,16} In addition, there is currently no investigation delving into the development of a model for accurately predicting the occurrence of CAUTI following radical hysterectomy for CC. In this study, the nomogram model we attempted to develop was simple, quantitative, and user-friendly. By incorporating key variables such as the duration of urinary catheterization, the presence of urinary leukocyte esterase, and urine culture results, the model aimed to present the probability of CAUTI occurrence. Moreover, the risk factor variables in this study were comprehensive and scientifically selected, covering risk factors throughout the entire hospitalization period. In addition, the AUC of the ROC reached 90.35%, indicating a high diagnostic accuracy. The DCA curve also displayed a noticeable clinical net benefit, effectively reflecting the performance and value of this model. The evaluation of patients' conditions by healthcare professionals is susceptible to subjectivity due to the impact of professional competence and clinical experience. To address this concern, a model was proposed to quantitatively establish the association between the risk factors for CAUTI following radical hysterectomy for CC. This model visually presents the relationship through a formula. It can enable healthcare professionals to focus on the potential risk of CAUTI in patients and identify high-risk patients for early detection of CAUTI. Consequently, this approach can facilitate the implementation of infection control measures, ultimately enhancing patient care. Furthermore, in the future, integrating this model into medical information systems could be considered, which would further streamline the identification and management of CAUTI risks, thereby improving patient outcomes and safety.¹⁹ This model provides a foundation for further applications and improvements in related models, offering valuable insights and references for future research and clinical practice.

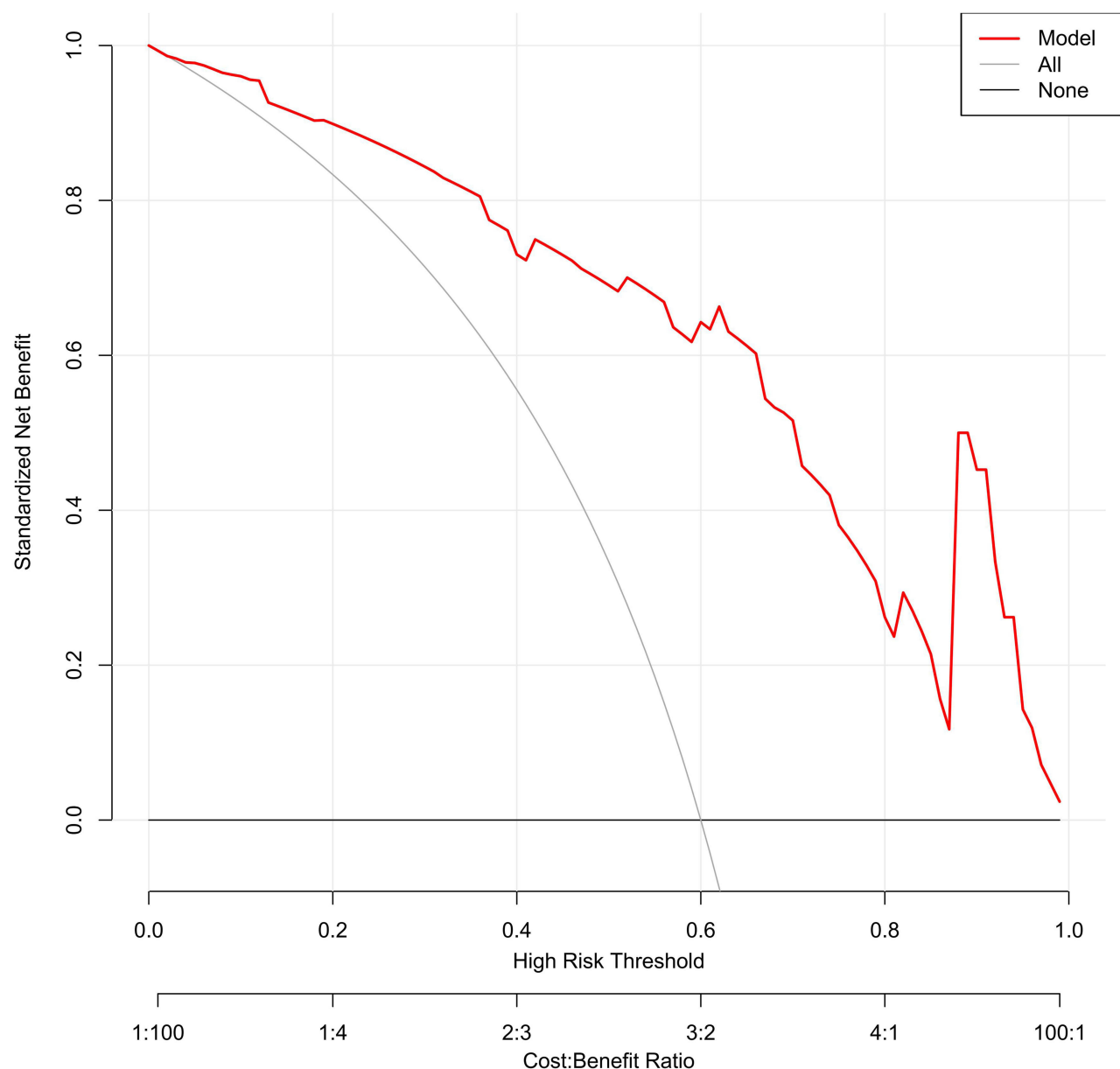


Figure 4 DCA curve of the model for CAUTI diagnosis after radical hysterectomy for CC.

Abbreviations: DCA, Decision curve analysis; CAUTI, catheter-associated urinary tract infection; CC, cervical cancer.

The findings of this study have significant implications for clinical practice, particularly in the care of patients undergoing radical hysterectomy for Cervical Cancer (CC). The identification of duration of urinary catheterization, urinary leukocyte esterase, and positive urine culture as independent risk factors for Catheter-Associated Urinary Tract Infections (CAUTI) underscores the importance of vigilant monitoring and management of these factors. Clinicians should be aware that prolonged catheterization, indicated by a positive urine culture, and the presence of leukocyte esterase can substantially increase the risk of CAUTI. Consequently, healthcare providers should aim to reduce the duration of catheterization, regularly monitor urine culture results, and test for urinary leukocyte esterase to mitigate infection risks. The development of a nomogram model with high accuracy (an area under the ROC curve of 90.35%) offers a valuable tool for clinicians to present the probability of CAUTI occurrence post-surgery. This model allows for more individualized patient care, enabling early interventions for those at higher risk. By integrating variables such as the duration of catheterization and urine test results into the nomogram, healthcare professionals can make more

informed decisions regarding patient management, potentially reducing the incidence of CAUTI and improving patient outcomes.

However, there are some limitations to the study. Firstly, this study is a single-center study, which may limit the generalizability of its results. Secondly, other potential risk factors for CAUTI, such as the efficacy of interventions targeting the identified risks, remain unexplored. Thirdly, although the data in this study were utilized for PSM, which greatly assisted in identifying risk factors, it did impose limitations on the construction of the prediction model. Nonetheless, this study made an attempt to develop a model, with the intention of providing a useful reference for future related research endeavors.

Conclusions

In conclusion, the duration of catheterization, urinary leukocyte esterase, and urine culture results have been identified as independent risk factors for CAUTI following radical hysterectomy for CC. The constructed nomogram model exhibits characteristics of simplicity, user-friendliness, high accuracy, and significant clinical value. Hence, it can serve as a valuable reference for supporting early clinical diagnosis decisions of CAUTI following radical hysterectomy for CC. Future research could focus on validating the model's universality, enhancing its precision, and investigating strategies to mitigate the risk of CAUTI following such gynecological surgeries.

Abbreviations

CAUTI, Catheter-associated Urinary Tract Infection; CC, Cervical Cancer; PSM, Propensity Score Matching; ROC, Receiver Operating Characteristic; DCA, Decision Curve Analysis.

Data Sharing Statement

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

Ethical Statement

We carried out this study according to the revised Declaration of Helsinki, and the ethics committee of the First Affiliated Hospital of Nanjing Medical University approved the study with informed consent.

Consent for Publication

We had obtained from the patient for written informed consent for publication.

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Author Contributions

Min Zhou and Hui Li are co-first authors. 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 declare no conflicts of interest in this work.

References

1. World Health Organization. Global cancer observatory: cancer today. Available from: <https://gco.iarc.fr/today/home>. Accessed December 20, 2024.
2. Health Commission of the People's Republic of China. Circular of the general office of the national health commission on the issuance of diagnostic and treatment guidelines for tumor and blood disease-related diseases (2022 Edition). State Health Office Medical Letter; 2022. Available from: <http://www.nhc.gov.cn/yzygj/s7659/202204/a0e67177df1f439898683e1333957c74/files/361f086b71214c4e8336fa7d251dc020.pdf>. Accessed December 20, 2024.
3. National Health and Family Planning Commission of the People's Republic of China. WS 509-2016 Specification for the prevention and control of hospital infection in intensive care units [S]. Beijing, 2016.
4. Li X, Zheng R, Li X, et al. Trends of incidence rate and age at diagnosis for cervical cancer in China, from 2000 to 2014[J]. *Chin J Cancer Res*. 2017;29(06):477–486. doi:10.21147/j.issn.1000-9604.2017.06.02
5. Mercadel AJ, Holloway SB, Saripella M, et al. Risk factors for catheter-associated urinary tract infections following radical hysterectomy for cervical cancer[J]. *Am J Obstet Gynecol*. 2023;228(6):711–718. doi:10.1016/j.ajog.2023.02.019
6. Yanfei B, Xiaoding Z, Liying Y. Status of urinary tract infection after cervical cancer surgery analysis of characteristics of infectious pathogens and risk factors[J]. *China Maternal Child Health Care*. 2023;38(01):81–84.
7. Ting Y, Chen R, Chunhong L, Xiang X, Mingmei D, Enfeng Z. The role of standardized management model in preventing urinary tract infection after cervical cancer surgery[J]. *Chinese J Hospital Infect*. 2022;32(19):3031–3035.
8. Novackova M, Pastor Z, Chmel R, Brtnicky T, Chmel R. Urinary tract morbidity after nerve sparing radical hysterectomy in women with cervical cancer. *Int Urogynecol J*. 2020;31(5):981–987. doi:10.1007/s00192-019-04083-9
9. Paek J, Kang E, Lim PC. Comparative analysis of genitourinary function after type C1 robotic nerve-sparing radical hysterectomy versus type C2 robotic radical hysterectomy. *Surg Oncol*. 2019;30:58–62.
10. Laterza RM, Sievert KD, de Ridder D, et al. Bladder function after radical hysterectomy for cervical cancer: bladder function after radical hysterectomy. *Neurourol Urodynam*. 2015;34(4):309–315. doi:10.1002/nau.22570
11. Chan JK, Gardner AB, Mann AK, Kapp DS. Hospital-acquired conditions after surgery for gynecologic cancer - an analysis of 82,304 patients. *Gynecol Oncol*. 2018;150(3):515–520. doi:10.1016/j.ygyno.2018.07.009
12. Xiao Y, Lihua X, Xiaomin X, Yan Z. Analysis of risk factors for hospital infection after radical surgery in patients with cervical cancer[J]. *Chinese J Hospital Infect*. 2014;4869–4870+4873.
13. Narducci F, Collinet P, Merlot B, et al. Benefit of robot-assisted laparoscopy in nerve-sparing radical hysterectomy: urinary morbidity in early cervical cancer. *Surg Endosc*. 2013;27(4):1237–1242. doi:10.1007/s00464-012-2582-z
14. Cardosi RJ, Cardosi RP, Grendys EC, Fiorica JV, Hoffman MS. Infectious urinary tract morbidity with prolonged bladder catheterization after radical hysterectomy. *Am J Obstet Gynecol*. 2003;189(2):380–383. doi:10.1067/S0002-9378(03)00696-3
15. Shuke Y, Yuqin W, Ling T, et al. Catheter-associated urinary tract infection pathogens and their influencing factors after cervical cancer surgery[J]. *Chinese J Hospital Infect*. 2021;31(12):1907–1910.
16. Dong L. Targeted monitoring and nursing intervention for catheter-related urinary tract infection in patients undergoing radical cervical cancer surgery[J]. *J Guangzhou Med Univ*. 2016;44(03):130–131.
17. Zacharia BE, Deibert C, Gupta G, et al. Incidence, cost, and mortality associated with hospital-acquired conditions after resection of cranial neoplasms. *Neurosurgery*. 2014;74(6):638–647. doi:10.1227/NEU.0000000000000342
18. Ramanathan R, Duane TM. Urinary tract infections in surgical patients. *Surg Clin North Am*. 2014;94(6):1351–1368. doi:10.1016/j.suc.2014.08.007
19. Liyao X, Chunlan W, Shuying L. Establishment and validation of a predictive model for the risk of postoperative catheter-related urinary tract infection in patients with gynecologic malignancies[J]. *Chinese J Modern Nursing*. 2022;28(06):809–813.
20. Ministry of Health of the People's Republic of China. Diagnostic criteria for hospital-acquired infections (for trial implementation)[J]. *Chinese Med J*. 2001;05:61–67.
21. Xiaoju M, Ying Y, Yan L, et al. Establishment and verification of a Nomogram model of intracranial infection after neurosurgery [J]. *Chin J Infect Control*. 2019;22(12):1483–1492.
22. Ziqiang H, Shuibin Y, Xunsong W, et al. Influencing factors of surgical site infection based on propensity score matching: a real-world study [J]. *Chin J Infect Control*. 2019;22(02):189–194.
23. Yan Y. Analysis of risk factors for urinary tract infection in patients with indwelling urinary catheter after radical surgery for uterine cervical cancer[J]. *China Med Innov*. 2022;19(11):104–107.
24. Xia L, Aifeng Y, Juan D, Dong L, Yan G. Analysis of factors related to postoperative urinary tract infection in patients with cervical cancer and investigation of the effect of bladder function training on the prevention of urinary retention[J]. *Chinese J Hospital Infect*. 2017;27(07):1612–1615.
25. Mingli Y, Ruiying C. Clinical significance of quantitative urine analysis parameters and routine urine leukocyte esterase test in urinary tract infection[J]. *Jiangxi Med*. 2022;57(10):1562–1564+1571.
26. Machida H, Hom MS, Shabalova A, Grubbs BH, Matsuo K. Predictive model of urinary tract infection after surgical treatment for women with endometrial cancer. *Arch Gynecol Obstet*. 2017;296(2):335–343. doi:10.1007/s00404-017-4434-5

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