Original Article

A web-based predictive model for secondary skin infections in breast cancer patients undergoing reconstruction

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Background: Breast cancer (BC) is one of the most common malignancies in women worldwide, with surgical interventions such as mastectomy and implant-based reconstruction playing a key role in management. While implant-based reconstruction offers immediate breast contour restoration, complications such as infection, capsular contracture, and implant failure are influenced by patient-specific factors, including age, body mass index (BMI), smoking, and adjuvant therapies like radiation. This study aimed to develop a predictive model for postoperative skin infections to enhance personalized risk assessment and optimize surgical outcomes in BC patients.

Methods: This retrospective study included 166 Chinese female patients with BC who underwent unilateral mastectomy followed by implant-based reconstruction. Univariate and multivariate logistic regression analyses were conducted to identify independent risk factors for postoperative skin infections. A nomogram was constructed based on significant variables, with its accuracy assessed using receiver operating characteristic (ROC) curves, calibration curves, and decision curve analysis (DCA).

Results: The 166 patients were divided into training and validation cohorts (6:4). Univariate analysis identified BMI, chemotherapy, radiotherapy, and prosthesis thickness as significant factors for postoperative skin infections. Multivariate analysis confirmed BMI, chemotherapy, and prosthesis thickness as independent risk factors. The predictive model demonstrated strong performance, with area under the curve (AUC) values of 0.87 and 0.812 for the training and validation cohorts, respectively. Calibration curves showed good agreement between predicted and observed outcomes, and DCA confirmed the model's clinical utility. A web-based calculator was developed to estimate infection risk (https://kevinpan.shinyapps.io/InfectionStatus/).

Conclusions: BMI, prosthesis thickness, and chemotherapy are key factors influencing the risk of postoperative skin infections in BC patients undergoing implant-based reconstruction. The predictive model developed in this study provides a valuable tool for clinicians to assess risk and personalize treatment plans. Further studies with larger cohorts are needed to validate and refine the model for broader clinical use.

Keywords: Breast cancer (BC); skin infection; breast reconstruction; predictive model; risk factors

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Introduction

Breast cancer (BC) remains one of the most prevalent malignancies affecting women globally, with various treatment modalities available depending on the stage and characteristics of the disease (1,2). While targeted therapies, endocrine treatments, and chemotherapy have advanced significantly in recent years, surgical intervention remains the cornerstone of BC management (2-4). Surgical options primarily include breast-conserving surgery (lumpectomy) and mastectomy, with the choice often influenced by tumor size, location, and patient preference (5). Among these, mastectomy, the complete removal of the breast, is frequently employed to achieve local control of the disease. Following mastectomy, breast reconstruction, particularly prosthetic implant-based reconstruction, plays a vital role in restoring the physical appearance of the breast and enhancing the psychological well-being of patients (6,7). Although this method offers the advantage of immediate breast contour restoration and involves a less complex surgical procedure, the variability in outcomes due to patient-specific factors underscores the importance of understanding and predicting the risks associated with implant-based reconstruction (7,8).

Clinical and patient-specific factors significantly affect the success of breast implant surgery. Age, body mass index (BMI), comorbidities like diabetes, and lifestyle choices such as smoking increase the risk of complications like infections, delayed healing, and implant failure (9-11). Tumor characteristics and adjuvant therapies, such as chemotherapy or radiotherapy, also influence outcomes (12,13). Radiation therapy increases the risk of capsular contracture, where scar tissue forms around the implant, causing discomfort and aesthetic issues (14,15). Other common complications include seroma, implant displacement, and rupture, which can impact physical outcomes and patient satisfaction. These complexities highlight the need for thorough preoperative evaluations to minimize risks and create personalized treatment plans for better surgical results.

This study aims to address this gap by analyzing various clinical factors associated with BC patients undergoing prosthetic implant-based reconstruction. By utilizing demographic, oncological, and treatment-related data, we developed a predictive model to assess the likelihood of complications following implant surgery. This model provides personalized risk assessments, enabling clinicians to make more informed decisions and optimize surgical outcomes. Ultimately, this approach aims to improve patient care by minimizing complications and enhancing the overall success of breast reconstruction procedures for BC survivors. We present this article in accordance with the TRIPOD reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-24-470/rc).

Highlight box

Key findings

- In a retrospective study of 166 breast cancer patients undergoing implant-based reconstruction, body mass index (BMI), chemotherapy, and prosthesis thickness were identified as independent risk factors for postoperative skin infections. A predictive model was developed, showing strong discriminative ability with area under the curve (AUC) values of 0.87 and 0.812 in training and validation cohorts, respectively. A web-based calculator was created to facilitate easy risk assessment for clinicians.

What is known and what is new?

- Complications, including infections, can occur after implant-based breast reconstruction, influenced by factors such as age, BMI, smoking, and adjuvant therapies.
- This study introduces a novel predictive model specifically targeting postoperative skin infections, quantifying the impact of key risk factors and providing a practical tool for personalized risk assessment.

What is the implication, and what should change now?

- The predictive model enables clinicians to assess individual infection risk, potentially improving patient counseling and tailoring surgical and postoperative care. Integration of the web-based calculator into clinical practice could enhance decision-making. Further validation in larger, multi-center studies is recommended to confirm the model's applicability across diverse populations. Clinicians should consider incorporating this risk assessment tool into preoperative evaluations to optimize patient outcomes.

Methods

Study patients and data collection

A retrospective study was conducted involving Chinese female BC patients treated in the Breast Surgery Department of The First Affiliated Hospital of Wenzhou Medical University between 2015 and 2021. The inclusion criteria were as follows: (I) BC patients aged 18 years or older; (II) patients who underwent unilateral mastectomy; (III) patients who received breast implant reconstruction following surgery. Exclusion criteria included: (I) patients with distant metastasis; (II) those who had undergone

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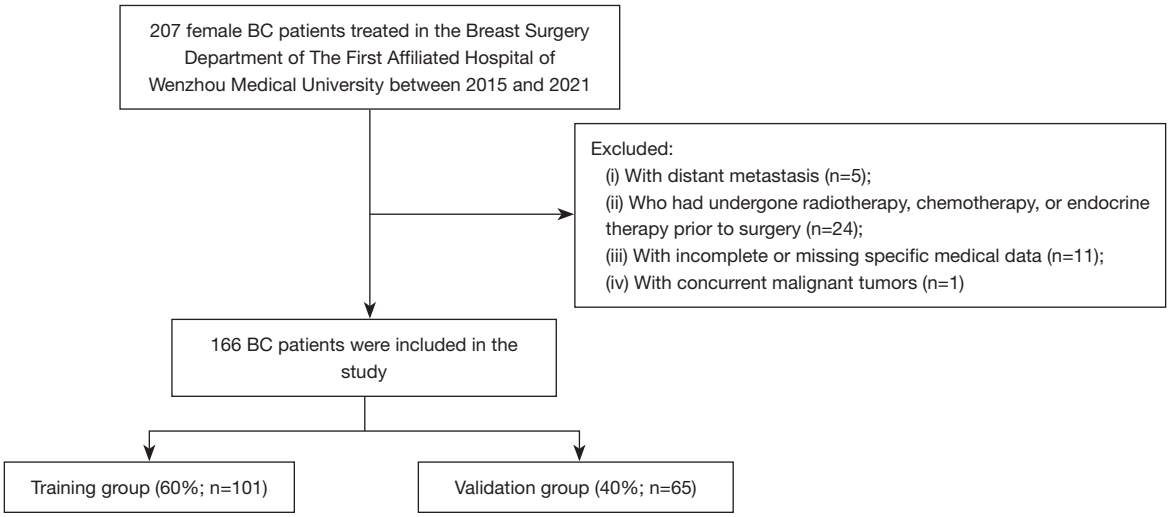

Figure 1 Patient selection flowchart. Flowchart showing the inclusion of 166 breast cancer patients from an initial cohort of 207. Patients were divided into training (n=101) and validation (n=65) groups after applying exclusion criteria. BC, breast cancer.

radiotherapy, chemotherapy, or endocrine therapy prior to surgery; (III) patients with incomplete or missing specific medical data; (IV) patients with concurrent malignant tumors. A total of 207 patients were initially considered for the study. After applying the inclusion and exclusion criteria, 166 patients were ultimately enrolled in the final cohort (*Figure 1*). The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. Ethics approval was obtained from the Ethics Committee of the Breast Surgery Department at The First Affiliated Hospital of Wenzhou Medical University (No. KY2024-R27). The requirement for written informed consent was waived due to the retrospective nature of the study.

Data collection

Pathological information collected from each patient included the following: duration of hospitalization (in days), number of dressing changes, clinical staging, patient age (in years), BMI (kg/m^2), histology type, lymph node metastasis count, chemotherapy, radiotherapy, targeted therapy, endocrine therapy, prosthesis volume (cm^3), prosthesis thickness, use of mesh, use of tissue expander, postoperative inflammatory lymph nodes, smoking status, preoperative white blood cell count (WBC)/postoperative WBC, preoperative neutrophil/postoperative neutrophil, and skin infection status. Clinical staging was classified according to the American Joint Committee on Cancer tumor-node-metastasis (TNM) staging system. The pathological types of BC were classified into invasive ductal carcinoma (IDC), ductal carcinoma *in situ* (DCIS), and others. All BC patients received radiotherapy using intensity-modulated radiation therapy (IMRT). In our study, implant thickness was measured intraoperatively using a sterile digital caliper, and the measurement refers to the maximum anterior-posterior height (in cm) of the implant, as provided by the manufacturer and confirmed in the operating room (Figure S1). Postoperative skin infection was defined as a clinically diagnosed infectious complication localized to the surgical site following implant-based breast reconstruction. This includes confirmed local signs of infection such as erythema with purulent drainage, wound dehiscence with positive microbial culture, abscess formation, and implant exposure secondary to infection. Minor complications such as localized seroma without signs of infection, mild erythema resolving without antibiotics, or non-infectious itching were explicitly excluded from this definition.

Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics version 25.0 and R software version 4.1.2. Continuous variables were reported as means with standard deviations (SDs) or as medians with interquartile ranges, depending on the data distribution, while categorical data were presented as frequencies and percentages. To compare baseline characteristics between patient groups, the Mann-

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Whitney *U* test was applied for continuous variables, and the Pearson χ^2 test was used for categorical variables. In the univariate analysis, variables with a P value of less than 0.05 were considered statistically significant and were subsequently included in a multivariate logistic regression model. This analysis aimed to identify independent risk factors for postoperative skin infection in BC patients who underwent prosthetic implantation. Significant variables from the multivariate analysis (P<0.05) were then selected to construct a nomogram using R software. The predictive accuracy and calibration of the nomogram were evaluated through receiver operating characteristic (ROC) curves, which assessed the model's discriminative ability, and calibration curves, which tested the agreement between predicted and observed outcomes. To further assess the clinical utility of the nomogram, decision curve analysis (DCA) was employed, quantifying the net benefit across various probability thresholds. Finally, to simplify the practical application of the nomogram, a web-based dynamic calculator was developed, providing an accessible tool for clinicians to predict the likelihood of postoperative skin infections based on individual patient characteristics.

Results

Baseline characteristics of the patients

Baseline clinical characteristics of the patients are listed in *Tables 1*,*2*. Among the 166 patients included in the study, 30 patients (18.07%) developed postoperative skin infections, while the remaining 136 patients (81.93%) did not experience any infection. Patients with skin infections had a mean age of 44.6 years (SD: 9.69), compared to a mean age of 42.4 years (SD: 8.04) in those without infections. The BMI was also higher in the infected group, with a mean of 24.1 kg/m^2 (SD: 2.69) versus 21.9 kg/m^2 (SD: 2.35) in the non-infected group. Notably, patients with skin infections had a higher mean lymph node metastasis count [1.50 (range, 0–9)] compared to those without infections [0.816 (range, 0–17)]. Furthermore, a higher proportion of patients in the infected group received chemotherapy (80%) compared to the non-infected group (39.7%). Similarly, 60% of the patients with infections had undergone radiotherapy, whereas only 16.9% of those without infections received radiotherapy. These findings suggest that older age, higher BMI, a greater number of lymph node metastases, and the receipt of chemotherapy and radiotherapy are more common among patients who developed postoperative skin infections.

In the study, the patients were randomly divided into a training group (60%) and a validation group (40%). Statistical analyses, including the Chi-squared test, Fisher's exact test, and Mann-Whitney *U* test, were conducted to compare the baseline characteristics between the two groups. No significant differences were found between the training and validation groups for any of the variables. This indicates that the random grouping was reliable, with no apparent bias in the distribution of baseline characteristics, ensuring the validity of the training and validation phases. The key variables were well balanced between the groups. Therefore, the randomization process effectively minimized potential confounding factors and supported the robustness of the model validation.

Logistic regression analysis results in the training group

In the univariate logistic regression analysis (*Table 3*), several factors were found to be significantly associated with postoperative skin infections in BC patients undergoing implant reconstruction. BMI was significantly associated with the risk of infection, with an odds ratio (OR) of 1.3072 [95% confidence interval (CI): 1.0744–1.5904, P=0.007], indicating that a higher BMI increased the likelihood of infection. Chemotherapy also showed a significant association with postoperative infections, with an OR of 9.8462 (95% CI: 1.2452–77.8541, P=0.03), suggesting that patients who received chemotherapy were at a greater risk. Radiotherapy was another significant factor, with an OR of 3.8231 (95% CI: 1.2319–11.8646, P=0.02). Additionally, prosthesis thickness showed a significant relationship with infections, with an OR of 1.1277 (95% CI: 1.0452–1.2167, P=0.002). In contrast, other factors, such as duration of hospitalization, number of dressing changes, clinical staging, histology type, lymph node metastasis count, targeted therapy, endocrine therapy, prosthesis volume, use of mesh, use of tissue expander, smoking status, and preoperative and postoperative WBC/neutrophil counts, were not statistically significant (P>0.05) in the univariate analysis.

In the multivariate logistic regression analysis, variables with a P value of less than 0.05 in the univariate analysis were included to adjust for potential confounders. BMI remained a significant predictor of postoperative infection, with an adjusted OR of 1.3329 (95% CI: 1.0398–1.7087, P=0.02). Chemotherapy continued to show a strong association with infection, with an adjusted OR of 34.0813 (95% CI: 2.1166–548.7675, P=0.01). Although

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Table 1 Patient baseline characteristics

Variables	Infection status (no) (N=136)	Infection status (yes) (N=30)	Overall (N=166)
Duration of hospitalization (days)			
Mean ± SD	7.82±4.25	7.87±5.99	7.83±4.59
Median [Min, Max]	7.00 [2.00, 20.0]	5.50 [2.00, 28.0]	6.00 [2.00, 28.0]
Number of dressing changes			
Mean ± SD	2.41±1.49	3.13±3.50	2.54±2.01
Median [Min, Max]	2.00 [1.00, 8.00]	2.00 [1.00, 17.0]	2.00 [1.00, 17.0]
Clinical staging, n (%)			
III	13 (9.6)	2 (6.7)	15 (9.0)
IVA	41 (30.1)	12 (40.0)	53 (31.9)
IVB	52 (38.2)	5 (16.7)	57 (34.3)
IVC	25 (18.4)	10 (33.3)	35 (21.1)
V	5 (3.7)	1 (3.3)	6 (3.6)
Patient age (years)			
Mean ± SD	42.4±8.04	44.6±9.69	42.8±8.38
Median [Min, Max]	43.0 [25.0, 63.0]	44.5 [28.0, 70.0]	43.0 [25.0, 70.0]
Body mass index (kg/m^2)			
Mean ± SD	21.9±2.35	24.1±2.69	22.3±2.55
Median [Min, Max]	21.7 [16.4, 32.1]	23.7 [19.4, 29.9]	22.2 [16.4, 32.1]
Histology type, n (%)			
DCIS	42 (30.9)	6 (20.0)	48 (28.9)
IDC	85 (62.5)	19 (63.3)	104 (62.7)
Other	9 (6.6)	5 (16.7)	14 (8.4)
Lymph node metastasis count			
Mean ± SD	0.816±2.06	1.50±2.16	0.940±2.09
Median [Min, Max]	0 [0, 17.0]	0 [0, 9.00]	0 [0, 17.0]
Chemotherapy, n (%)			
No	54 (39.7)	4 (13.3)	58 (34.9)
Yes	82 (60.3)	26 (86.7)	108 (65.1)
Radiotherapy, n (%)			
No	113 (83.1)	18 (60.0)	131 (78.9)
Yes	23 (16.9)	12 (40.0)	35 (21.1)
Targeted therapy, n (%)			
No	112 (82.4)	26 (86.7)	138 (83.1)
Yes	24 (17.6)	4 (13.3)	28 (16.9)

Table 1 (*continued*)

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Table 1 (*continued*)

Variables	Infection status (no) (N=136)	Infection status (yes) (N=30)	Overall (N=166)
Endocrine therapy, n (%)			
No	37 (27.2)	11 (36.7)	48 (28.9)
Yes	99 (72.8)	19 (63.3)	118 (71.1)
Prosthesis volume (cm^3)			
Mean ± SD	202±61.1	222±48.3	205±59.4
Median [Min, Max]	190 [100, 440]	215 [155, 340]	190 [100, 440]
Prosthesis thickness (mm)			
Mean ± SD	45.3±6.57	52.9±7.83	46.7±7.39
Median [Min, Max]	44.0 [30.0, 69.0]	50.5 [41.0, 72.0]	46.5 [30.0, 72.0]
Use of mesh, n (%)			
No	111 (81.6)	19 (63.3)	130 (78.3)
Yes	25 (18.4)	11 (36.7)	36 (21.7)
Use of tissue expander, n (%)			
No	52 (38.2)	13 (43.3)	65 (39.2)
Yes	84 (61.8)	17 (56.7)	101 (60.8)
Postoperative inflammatory lymph nodes, n (%)			
No	86 (63.2)	14 (46.7)	100 (60.2)
Yes	50 (36.8)	16 (53.3)	66 (39.8)
Smoking status, n (%)			
No	112 (82.4)	21 (70.0)	133 (80.1)
Yes	24 (17.6)	9 (30.0)	33 (19.9)
Preoperative WBC/postoperative WBC			
Mean ± SD	1.12±0.467	1.08±0.504	1.12±0.473
Median [Min, Max]	1.02 [0.510, 4.34]	0.960 [0.232, 2.65]	1.02 [0.232, 4.34]
Preoperative neutrophil/postoperative neutrophil			
Mean ± SD	1.46±2.48	1.20±1.01	1.41±2.29
Median [Min, Max]	1.09 [0.304, 29.0]	1.01 [0.103, 5.93]	1.06 [0.103, 29.0]

DCIS, ductal carcinoma in situ; IDC, invasive ductal carcinoma; SD, standard deviation; WBC, white blood cell count.

radiotherapy approached significance, it did not meet the threshold for statistical significance in the multivariate analysis (OR: 3.482, 95% CI: 0.8058–15.0459, P=0.09). Prosthesis thickness remained a significant factor, with an adjusted OR of 1.1622 (95% CI: 1.0431–1.2949, P=0.006). These results indicate that higher BMI, chemotherapy and increased prosthesis thickness are independent risk factors for the development of postoperative skin infections in this patient population.

Establishment and prediction of the predictive model

To enhance the interpretability of our predictive model, we constructed a nomogram that encompasses all statistically significant risk factors from the multivariate logistic regression model (BMI, chemotherapy, prosthesis thickness)

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Table 2 Characteristics of the training and validation sets of 166 patients

Variables	Training (N=101)	Validation (N=65)	Overall (N=166)	P value
Duration of hospitalization (days)				0.55
Mean ± SD	7.45±3.95	8.42±5.43	7.83±4.59	
Median [Min, Max]	6.00 [2.00, 18.0]	7.00 [2.00, 28.0]	6.00 [2.00, 28.0]	
Number of dressing changes				0.39
Mean ± SD	2.29±1.31	2.94±2.73	2.54±2.01	
Median [Min, Max]	2.00 [1.00, 7.00]	2.00 [1.00, 17.0]	2.00 [1.00, 17.0]	
Clinical staging, n (%)				0.27
III	7 (6.9)	8 (12.3)	15 (9.0)	
IVA	35 (34.7)	18 (27.7)	53 (31.9)	
IVB	30 (29.7)	27 (41.5)	57 (34.3)	
IVC	25 (24.8)	10 (15.4)	35 (21.1)	
V	4 (4.0)	2 (3.1)	6 (3.6)	
Patient age (years)				0.06
Mean ± SD	41.9±8.09	44.1±8.70	42.8±8.38	
Median [Min, Max]	43.0 [25.0, 60.0]	44.0 [28.0, 70.0]	43.0 [25.0, 70.0]	
Body mass index (kg/m^2)				0.95
Mean ± SD	22.5±2.79	22.1±2.11	22.3±2.55	
Median [Min, Max]	22.2 [16.4, 32.1]	22.0 [17.8, 27.7]	22.2 [16.4, 32.1]	
Histology type, n (%)				0.22
DCIS	33 (32.7)	15 (23.1)	48 (28.9)	
IDC	58 (57.4)	46 (70.8)	104 (62.7)	
Other	10 (9.9)	4 (6.2)	14 (8.4)	
Lymph node metastasis count				0.99
Mean ± SD	0.802±1.57	1.15±2.70	0.940±2.09	
Median [Min, Max]	0 [0, 9.00]	0 [0, 17.0]	0 [0, 17.0]	
Chemotherapy, n (%)				>0.99
No	35 (34.7)	23 (35.4)	58 (34.9)	
Yes	66 (65.3)	42 (64.6)	108 (65.1)	
Radiotherapy, n (%)				0.76
No	81 (80.2)	50 (76.9)	131 (78.9)	
Yes	20 (19.8)	15 (23.1)	35 (21.1)	
Targeted therapy, n (%)				0.84
No	83 (82.2)	55 (84.6)	138 (83.1)	
Yes	18 (17.8)	10 (15.4)	28 (16.9)	

Table 2 (*continued*)

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Table 2 (*continued*)

Variables	Training (N=101)	Validation (N=65)	Overall (N=166)	P value
Endocrine therapy, n (%)				0.80
No	28 (27.7)	20 (30.8)	48 (28.9)	
Yes	73 (72.3)	45 (69.2)	118 (71.1)	
Prosthesis volume (cm^3)				0.73
Mean ± SD	214±62.8	192±51.4	205±59.4	
Median [Min, Max]	190 [100, 440]	180 [100, 340]	190 [100, 440]	
Prosthesis thickness (mm)				0.45
Mean ± SD	47.3±7.44	45.8±7.29	46.7±7.39	
Median [Min, Max]	48.0 [30.0, 72.0]	44.0 [32.0, 72.0]	46.5 [30.0, 72.0]	
Use of mesh, n (%)				0.17
No	75 (74.3)	55 (84.6)	130 (78.3)	
Yes	26 (25.7)	10 (15.4)	36 (21.7)	
Use of tissue expander, n (%)				0.50
No	37 (36.6)	28 (43.1)	65 (39.2)	
Yes	64 (63.4)	37 (56.9)	101 (60.8)	
Postoperative inflammatory lymph nodes, n (%)				0.66
No	59 (58.4)	41 (63.1)	100 (60.2)	
Yes	42 (41.6)	24 (36.9)	66 (39.8)	
Smoking status, n (%)				0.57
No	79 (78.2)	54 (83.1)	133 (80.1)	
Yes	22 (21.8)	11 (16.9)	33 (19.9)	
Preoperative WBC/postoperative WBC				0.98
Mean ± SD	1.12±0.505	1.11±0.422	1.12±0.473	
Median [Min, Max]	1.01 [0.232, 4.34]	1.02 [0.572, 2.88]	1.02 [0.232, 4.34]	
Preoperative neutrophil/postoperative neutrophil				0.97
Mean ± SD	1.48±2.84	1.31±0.959	1.41±2.29	
Median [Min, Max]	1.07 [0.103, 29.0]	1.06 [0.489, 5.93]	1.06 [0.103, 29.0]	
Infection status, n (%)				0.18
No	79 (78.2)	57 (87.7)	136 (81.9)	
Yes	22 (21.8)	8 (12.3)	30 (18.1)	

DCIS, ductal carcinoma in situ; IDC, invasive ductal carcinoma; SD, standard deviation; WBC, white blood cell count.

to assist clinicians in evaluating the risk of skin infection after implant-based reconstruction in BC patients. Based on the regression coefficients, a score is assigned to each variable by drawing a straight line above the reference line, and a total score is obtained by summing the scores for the 3 predictive variables. The corresponding risk can then be estimated by drawing a line labeled "Risk" on the axis of the nomogram (*Figure 2*). ROC analysis was conducted

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Table 3 Results of univariate and multivariate logistic regression analysis

Clinical characteristics	Univariable			Multivariable		
	OR	95% CI	P value	OR	95% CI	P value
Duration of hospitalization (days)	0.9559	0.8431–1.0837	0.48			
Number of dressing changes	1.0796	0.8704–1.339	0.49			
Clinical staging						
III						
IVA	1.7778	0.1856–17.0243	0.62			
IVB	0.7742	0.0707–8.4742	0.83			
IVC	3.2	0.3259–31.4212	0.32			
V	2.6667	0.1234–57.6233	0.53			
Patient age (years)	1.0315	0.9701–1.0969	0.32			
Body mass index (kg/m^2)	1.3072	1.0744–1.5904	0.007*	1.3329	1.0398–1.7087	0.02*
Histology type						
DCIS						
IDC	1.4	0.4017–4.8788	0.60			
Other	3.5	0.616–19.888	0.16			
Lymph node metastasis count	1.029	0.8297–1.2761	0.79			
Chemotherapy						
No						
Yes	9.8462	1.2452–77.8541	0.03*	34.0813	2.1166–548.7675	0.01*
Radiotherapy						
No						
Yes	3.8231	1.2319–11.8646	0.02*	3.482	0.8058–15.0459	0.09
Targeted therapy						
No						
Yes	1.4221	0.3511–5.7602	0.62			
Endocrine therapy						
No						
Yes	0.6913	0.2291–2.0856	0.51			
Prosthesis volume (cm^3)	1.0066	0.9976–1.0157	0.15			
Prosthesis thickness (mm)	1.1277	1.0452–1.2167	0.002*	1.1622	1.0431–1.2949	0.006*
Use of mesh						
No						
Yes	1.6422	0.509–5.2975	0.41			
Use of tissue expander						
No						
Yes	1.7386	0.6095–4.9596	0.30			

Table 3 (*continued*)

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Table 3 (*continued*)

Clinical characteristics	Univariable			Multivariable		
	OR	95% CI	P value	OR	95% CI	P value
Postoperative inflammatory lymph nodes						
No						
Yes	0.8437	0.2965–2.4011	0.75			
Smoking status						
No						
Yes	1.9167	0.587–6.2583	0.28			
Preoperative WBC/postoperative WBC	0.5352	0.1273–2.2505	0.39			
Preoperative neutrophil/postoperative neutrophil	0.8973	0.4729–1.7023	0.74			

*, denotes statistically significant values with a P value of <0.05. CI, confidence interval; DCIS, ductal carcinoma in situ; IDC, invasive ductal carcinoma; OR, odds ratio; WBC, white blood cell count.

for both the training and validation cohorts to assess the diagnostic accuracy of the model (*Figure 3*). The ROC curve demonstrated that the model had a high efficiency in predicting survival outcomes, with area under the curve (AUC) values of 0.87 (95% CI: 0.7944–0.9465) and 0.872 (95% CI: 0.6719–0.9523) for the training and validation cohorts, respectively. These results indicate that the model exhibits good discriminatory ability in distinguishing the presence or absence of skin infection risk following implant-based reconstruction in BC patients, as evidenced by the high AUC values.

Furthermore, calibration curves were plotted to evaluate the model's performance in the training and validation cohorts. The predicted values showed good agreement with the observed values in both the training cohort (mean absolute error =0.028) and the validation cohort (mean absolute error =0.031). The calibration curves demonstrate that the model has good calibration ability (*Figure 4*).

Figure 5 shows DCA for the training set and training set. The red line represents the model's net benefit across different high-risk thresholds, compared to the gray "treat all" line. The model provides positive net benefit at certain thresholds, indicating potential clinical value in risk prediction.

To simplify the use of the nomogram, we created a web-based dynamic calculator, accessible at https://kevinpan.shinyapps.io/InfectionStatus/. By entering specific clinical characteristics, users can calculate the predicted infection probability along with its 95% CI. For example, a BC patient with a BMI of 28 kg/m^2, a prosthesis thickness of 52 mm, and no adjuvant chemotherapy has an estimated 18.5% risk of developing ipsilateral skin infection, with a 95% CI ranging from 0.031 to 0.616, as demonstrated in *Figure 6*.

Discussion

BC is one of the most prevalent malignancies affecting women worldwide. While advancements in targeted therapies, chemotherapy, and endocrine treatments have greatly improved patient outcomes, surgery remains a cornerstone of BC treatment. Mastectomy followed by implant-based reconstruction is a common approach that restores breast contour and enhances psychological well-being. However, postoperative complications, particularly skin infections, can adversely affect both the clinical outcome and patient satisfaction. This study aimed to identify clinical factors associated with infection risk in BC patients undergoing implant-based reconstruction and to develop a predictive model to assist clinicians in assessing these risks. In our analysis, three factors—BMI, prosthesis thickness, and adjuvant chemotherapy—emerged as significant predictors of postoperative skin infection. Based on these three factors, we developed a predictive model to estimate the risk of postoperative skin infection in BC patients undergoing implant-based reconstruction. The model was validated using both training and validation cohorts, and a web-based dynamic calculator was subsequently created to provide clinicians with an easy-to-use tool for individualized risk prediction.

Several studies have investigated the role of BMI in

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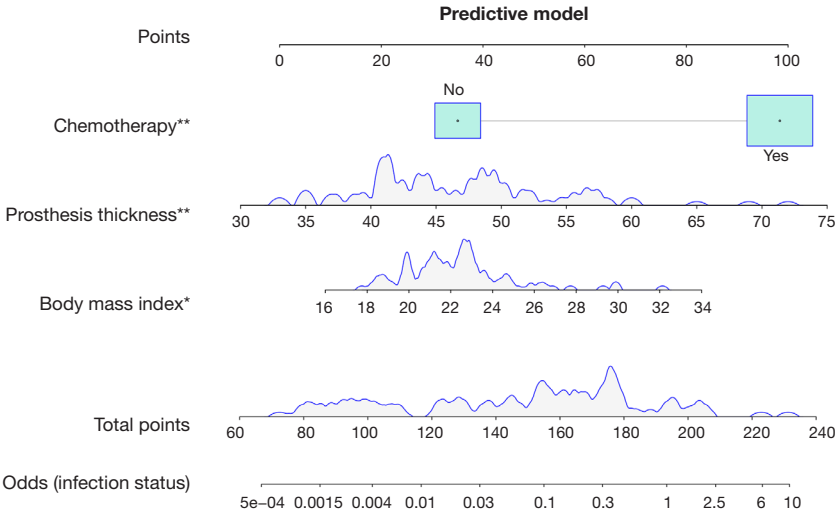

Figure 2 Nomogram for predicting postoperative skin infection risk in breast cancer patients. The nomogram integrates chemotherapy status, prosthesis thickness, and BMI to calculate the total points and predict the odds of postoperative skin infection. Higher total points correspond to increased infection risk. *, P<0.05; **, P<0.01. BMI, body mass index.

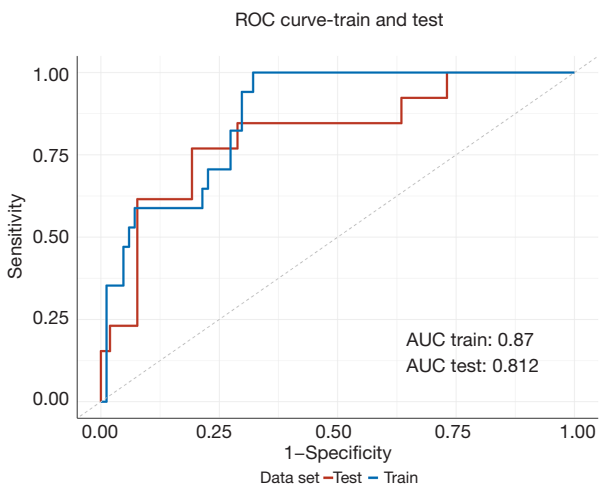

Figure 3 ROC curve for training and test data sets. ROC curves for the predictive model applied to the training and test data sets. The AUC is 0.87 for the training set and 0.812 for the test set, indicating good discriminative performance. AUC, area under the curve; ROC, receiver operating characteristic.

predicting complications following breast reconstruction, but the findings have been mixed (9,10,16-18). In a retrospective study by Leitner *et al.*, 196 breast reconstructions from 134 patients were analyzed to assess the impact of BMI on postoperative outcomes after implant-based reconstruction. The study found that while BMI was not significantly associated with increased complication rates, the overall complication rate was 30.5%, with common issues including impaired wound healing, seroma, and infection. Additionally, longer operative times were linked to higher complication rates and extended hospital stays (10). However, in a study by McCarthy *et al.*, 1,170 expander/implant reconstructions were performed in 884 patients, revealing that smoking, obesity, hypertension, and age over 65 years were significant independent risk factors for complications. The study found that smokers had 2.2 times greater odds of developing complications and a five-fold higher risk of reconstructive failure, while obese patients faced nearly double the odds of complications and a seven-fold increase in failure risk. These findings underscore the importance of evaluating individual risk factors to personalize reconstructive plans and minimize complications (9). Based on our study, BMI emerged as an independent risk factor for postoperative complications in implant-based breast reconstruction. Higher BMI was linked to increased risks of skin infections and impaired wound healing. Several mechanisms may explain this association: excess adipose tissue in individuals with higher BMI has reduced vascularity, impairing oxygen delivery and delaying wound healing. Additionally, the increased mechanical stress on the incision and implant can lead to complications such as wound dehiscence and seroma.

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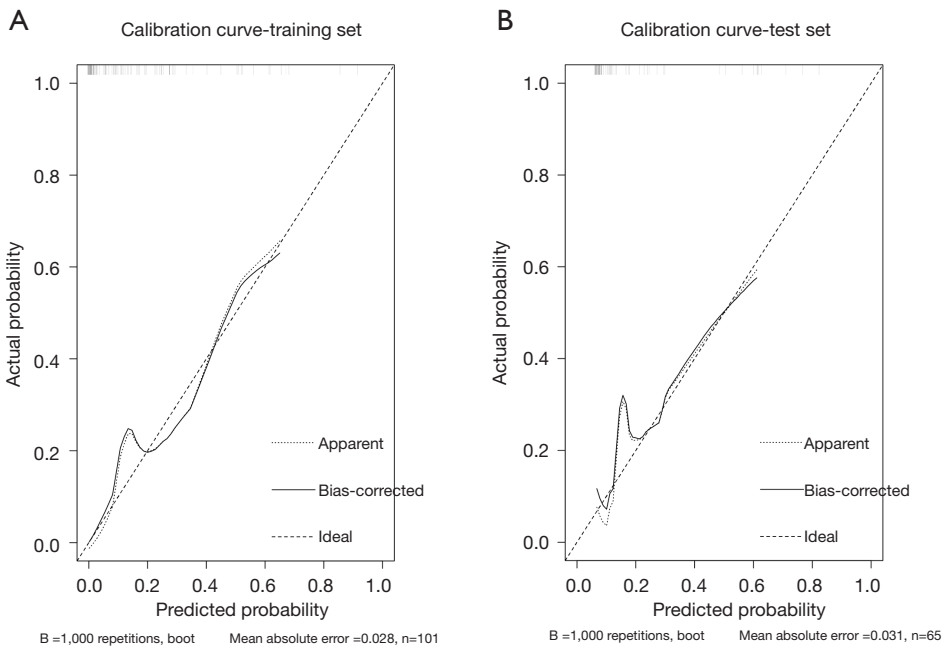

Figure 4 Calibration curves for the training and test sets. Calibration curves for the predictive model in (A) the training set and (B) the test set. The dashed line represents the ideal calibration, the solid line represents the bias-corrected calibration, and the dotted line represents the apparent calibration. The curves demonstrate the agreement between predicted probabilities and actual probabilities, with mean absolute errors of 0.028 and 0.031 for the training and test sets, respectively.

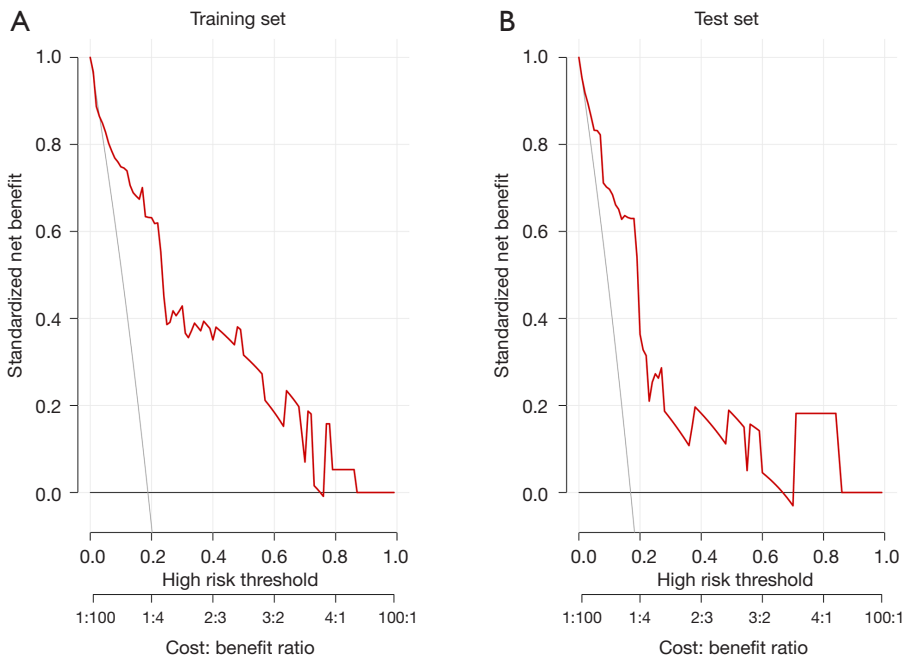

Figure 5 Decision curve analysis for the training and test sets. Decision curve analysis showing the standardized net benefit for the predictive model in (A) the training set and (B) the test set across a range of high-risk thresholds. The red line represents the net benefit of the model, demonstrating its clinical utility compared to default strategies of treating all or no patients.

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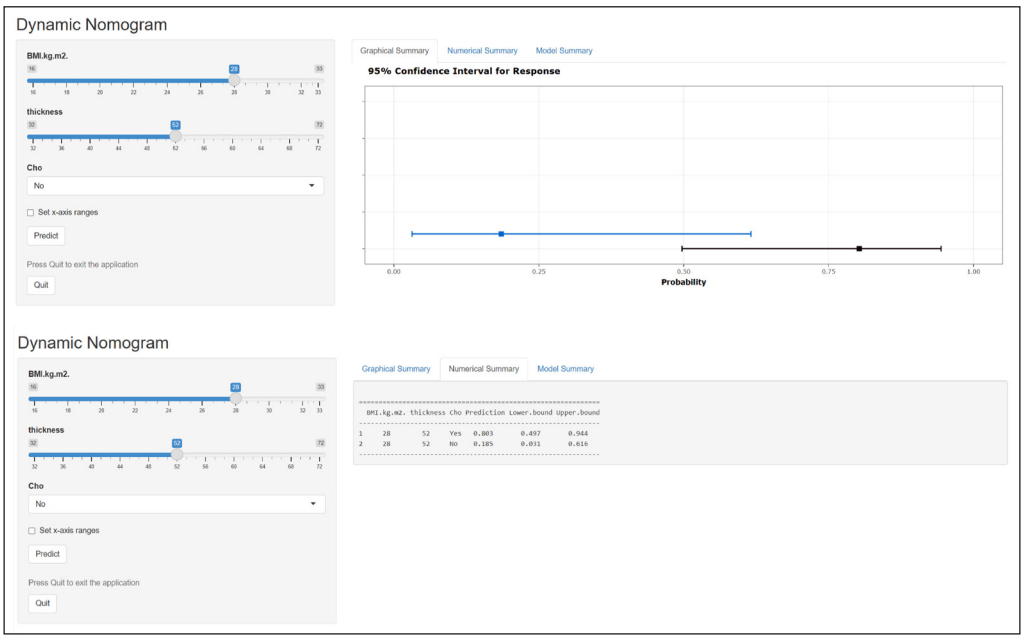

Figure 6 Dynamic nomogram for predicting skin infection risk. Interactive dynamic nomogram incorporating BMI, prosthesis thickness, and chemotherapy status. Users can adjust input variables to obtain personalized predictions of postoperative skin infection risk, along with 95% confidence intervals and detailed numerical summaries. BMI, body mass index.

Obesity is also associated with a chronic pro-inflammatory state and metabolic conditions like insulin resistance, which further impair immune response and healing, increasing the risk of complications (19,20). These findings underscore the importance of closely monitoring BMI as part of the preoperative assessment for breast reconstruction. Implementing strategies such as weight management before surgery may help reduce the risk of postoperative complications and improve overall surgical outcomes in this patient population.

The study by Yin *et al.* also identified prosthesis thickness as a risk factor for complications in breast reconstruction (21). The results showed that, compared to medium-thickness acellular dermal matrix (ADM), the use of thicker ADM was significantly associated with higher rates of infection (P<0.04) and wound complications (P<0.001). A thicker prosthesis may exert additional pressure on the overlying skin, increasing the risk of mechanical stress and tension, which can lead to skin breakdown and infection. This underscores the importance of carefully selecting prosthesis size during reconstruction to balance aesthetic outcomes while minimizing complications. Surgeons should take into account the patient's tissue characteristics when choosing the implant to prevent excessive tension and reduce the risk of infection.

Lee *et al.* conducted a study involving 602 cases across 568 patients, with a mean follow-up period of 58.5 months (22). The study demonstrated that adjuvant chemotherapy significantly increased the rates of overall complications in two-stage implant-based breast reconstruction, including infections (OR 4.239, 95% CI: 1.059–16.970, P<0.05), severe capsular contracture (OR 2.107, 95% CI: 1.067–4.159, P<0.05), and reconstruction failures (OR 12.754, 95% CI: 1.587–102.481, P<0.05). Furthermore, specific chemotherapy regimens, such as sequential anthracycline/cyclophosphamide and taxane, were associated with higher risks of adverse outcomes compared to patients who did not receive chemotherapy, while other regimens, such as anthracycline/cyclophosphamide alone, were not linked to these increased risks. The results of this study indicate that patients receiving chemotherapy are more likely to develop postoperative skin infections, possibly due to the immunosuppressive effects of chemotherapy, which can impair the body's ability to heal wounds and fight infections. Similarly, other studies have shown that neoadjuvant chemotherapy does not increase the risk of complications following breast reconstruction (12,13). Therefore, this study only included patients undergoing implant-based breast reconstruction who did not receive neoadjuvant treatment. In addition, radiotherapy was not included as a significant variable in our model. Traditionally,

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radiotherapy has been associated with an increased risk of complications, such as capsular contracture, delayed wound healing, and infections, especially in the context of breast reconstruction (23). This may be attributed to advances in radiotherapy techniques that have reduced the incidence of these complications. Modern techniques, such as IMRT, allow for more precise targeting of cancerous tissues while sparing surrounding healthy tissue, thereby minimizing the adverse effects traditionally associated with radiotherapy.

Despite the valuable insights gained from this study, several limitations should be acknowledged. The retrospective design inherently carries the risk of selection bias, and the sample size, while sufficient for initial analysis, may not fully capture the variability present in larger or more diverse populations. Since the study was conducted at a single institution, the results may not be directly applicable to other healthcare settings or patient populations, limiting the external validity of the findings. Future large-scale, multi-center studies are warranted to validate and refine this model to ensure its broader applicability across diverse clinical settings and populations. Nonetheless, this study offers significant strengths, including the development of a simple and effective predictive model based on easily accessible clinical factors. The nomogram and web-based calculator provide clinicians with a practical tool for assessing the individualized risk of postoperative skin infections. The model demonstrated high accuracy and reliability, as reflected by the strong performance in both the training and validation cohorts.

Conclusions

In conclusion, BMI, prosthesis thickness, and chemotherapy are critical factors influencing the risk of postoperative skin infections in BC patients undergoing implant-based reconstruction. By applying our predictive model, clinicians can better assess risk, personalize treatment plans, and ultimately improve patient outcomes. Further studies with larger cohorts and multi-center validation are needed to confirm these findings and refine the model for broader clinical use.

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Footnote

Reporting Checklist: The authors have completed the TRIPOD reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-24-470/rc

Data Sharing Statement: Available at https://gs.amegroups.com/article/view/10.21037/gs-24-470/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-24-470/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. Ethics approval was obtained from the Ethics Committee of the Breast Surgery Department at The First Affiliated Hospital of Wenzhou Medical University (No. KY2024-R27). The requirement for written informed consent was waived due to the retrospective nature of the study.

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