Article

Construction and Validation of a Risk Prediction Model for Peristomal Moisture-Associated Skin Damage in Older Patients With Enterostomies

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AIM: This study aimed to identify the risk factors for peristomal moisture-associated skin damage (PMASD) in older patients with enterostomies and to develop a predictive model.
METHODS: This is a retrospective study. Data were collected from older patients who underwent enterostomy at The Fifth Affiliated Hospital of Wenzhou Medical University in Lishui between January 2021 and December 2022. With peristomal moisture-associated skin damage as the outcome variable, predictors identified as significant in the univariate analysis were incorporated into a multivariate logistic regression model. The model's goodness-of-fit and discriminative ability were assessed using the Hosmer–Lemeshow test and the area under the receiver operating characteristic (ROC) curve (AUC). To further evaluate the model's stability and predictive performance, an internal validation was conducted using a time-stratified cohort of 68 patients consecutively recruited from the same hospital between January 2023 and December 2023.
RESULTS: The incidence of PMASD was 42.59% in the model development group (n = 162) and 41.18% in the validation group (n = 68). Independent predictors of PMASD included surgical incision in the stoma baseplate area (odds ratio [OR] = 4.80; 95% confidence interval [CI], 1.04–7.51), ileostomy (OR = 3.49; 95% CI, 1.27–7.99), history of radiotherapy (OR = 1.49; 95% CI, 1.05–2.10), lack of preoperative stoma marking (OR = 5.07; 95% CI, 2.50–8.30), and peristomal skin folds (OR = 3.96; 95% CI, 2.53–16.10), while stoma height $\geq$1.3 cm (OR = 0.11; 95% CI, 0.04–0.29) and continuity of care (OR = 0.60; 95% CI, 0.45–0.80) were protective factors. The model showed good discrimination (area under the receiver operating characteristic curve [AUC] = 0.90; 95% CI, 0.86–0.95) and calibration (Hosmer–Lemeshow p = 0.851) in the model development group and maintained strong performance in the validation group (AUC = 0.91; Hosmer–Lemeshow p = 0.875).
CONCLUSIONS: The validated prediction model demonstrated high discrimination (AUC >0.90) and good calibration, providing an effective tool for the early identification of older patients undergoing enterostomy at high risk of PMASD. This model may guide individualized preventive strategies and optimize the continuity of care. Further multicenter prospective studies are needed to confirm the generalizability and clinical utility of our findings.

Keywords: colorectal cancer; risk prediction model; intestinal stoma; moisture-associated skin damage; elderly patients

Introduction

Colorectal cancer is the third most commonly diagnosed malignancy and the second leading cause of cancer-related deaths worldwide, with over 60% of cases occurring in older adults [1]. Ostomy surgery, which is performed in approximately 35% of patients with colorectal cancer, remains one of the most common surgical interventions for this disease [2]. Peristomal moisture-associated skin damage (PMASD) manifests as impaired skin integrity or localized tissue loss at the interface between the stoma and the surrounding peristomal skin, and in severe cases, may progress to dermal involvement. With reported incidence rates ranging from 33% to 43%, PMASD occurs in both the early and late postoperative periods and poses substantial challenges to patient care [3,4]. The condition commonly presents with pain and pruritus and contributes to physical discomfort, increased psychological distress, reduced quality of life [5], and heightened economic burden due to prolonged treatment and complex wound management [6].

Older adults are particularly vulnerable to PMASD due to age-related declines in skin physiology, such as decreased epidermal turnover, reduced hydration, and diminished barrier function, combined with a higher prevalence of comorbidities and polypharmacy, which further compromise skin resilience. As the global population ages, United Nations projections indicate that by 2050, older adults will constitute nearly 20% of the world's population [7]. In China, this trend is especially pronounced, with more than 280 million individuals aged 60 years or older, accounting for 19.8% of the national population, signaling the country's rapid transition into a moderately aged society [8]. Given that over

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90% of colorectal cancer cases occur in individuals aged ≥50 years, the intersection of rising cancer burden and demographic aging underscores the urgent need for targeted preventive strategies in older populations. While previous studies have developed PMASD risk-prediction models (for example, Liu *et al*. [9] identified nine predictors and Wang *et al*. [10] used seven variables), these tools were primarily designed for the general adult population and lack specificity for older adults. Therefore, a critical gap remains in evidence-based tools tailored to older patients undergoing enterostomy, particularly within the Chinese context.

To address this gap, our study focused on developing a PMASD risk-prediction model specifically for older adults undergoing enterostomy, incorporating demographic characteristics, disease-related factors, and stoma-specific variables analyzed using multivariate logistic regression. This model aims to enable clinicians to identify high-risk individuals early, implement personalized preventive interventions, improve clinical outcomes, and ultimately enhance the quality of life of older adults living with stomas.

Methods

Study Design and Setting

A retrospective cohort study was conducted to identify predictive factors associated with the development of PMASD in older patients following enterostomy. Data were collected from electronic medical records, structured questionnaires, clinical observations, and post-discharge follow-up at The Fifth Affiliated Hospital of Wenzhou Medical University in Lishui. The primary outcome was the incidence of PMASD within three months after stoma creation. Based on a comprehensive review of current clinical guidelines, including those issued by the Chinese Society of Oncology and the Department of Health Administration of the National Health Commission [11,12], as well as guidance from the Surgery and Anesthesiology Branches of the Chinese Medical Association, and informed by expert consultation with clinicians and medical informatics specialists, 11 candidate predictors were selected. These predictors were categorized into four domains: demographic characteristics, disease-related factors, stoma-specific features, and stoma care-related parameters.

Study Population and Sampling

Participants were older adults (aged ≥65 years) who underwent elective or emergency creation of an intestinal stoma (enterostomy) between January 2021 and December 2023 at our institution. A two-phase sampling approach was used: patients treated from January 2021 to December 2022 comprised the model-development (training) cohort, and those managed from January to December 2023 formed the independent validation cohort. The sample size was determined using the events-per-variable (EPV) rule to ensure model stability, targeting 5–10 outcome events per candidate predictor. Assuming an estimated incidence of PMASD of 43% [9], a projected loss to follow-up of 15%, and a prespecified EPV of 9, the minimum required sample size was calculated as: Z = number of variables × 9 / 0.43 / 0.85 ≈ 271.

Consequently, the target minimum sample size was 271 participants. Initially, 275 patients were enrolled in the study. A complete case analysis was performed (no imputation), and 45 patients were excluded due to incomplete data or loss to follow-up. Specifically, 25 patients declined further contact, 12 had invalid telephone numbers, 6 died from causes unrelated to the stoma operation, and 2 relocated abroad. Thus, 230 patients with complete datasets were included in the final analysis, 162 in the modeling cohort and 68 in the validation cohort. Although the final number of analysable samples (n = 230) fell slightly short of the pre-specified target (n = 271), the observed number of events still provided an acceptable EPV, as detailed below. 11 candidate predictor variables were initially considered in this study. In the modelling cohort, 69 PMASD events were observed, yielding an EPV of 69/11 ≈ 6.27. Although this is slightly lower than the prespecified EPV of 9, it is still higher than the generally accepted minimum threshold of 5, indicating that model stability is still acceptable.

Inclusion and Exclusion Criteria

Eligible patients met all of the following inclusion criteria: age ≥65 years; underwent surgical creation of an intestinal stoma; had complete clinical data; and possessed intact cognitive and communication abilities as confirmed by clinical assessment. Exclusion criteria were: documented peristomal skin lesions prior to surgery; development of severe postoperative complications that would confound skin outcomes (e.g., anastomotic leakage, peristomal leak, or systemic infection); physical disabilities or neuromuscular disorders (e.g., poliomyelitis) that impaired independent stoma self-care; and psychiatric conditions or sensory impairments (e.g., clinically significant hearing loss) that would interfere with accurate data reporting or participation in follow-up.

Data Collection Instruments and Procedures

Three standardized instruments were used to collect the study data: (1) General Information Questionnaire: This form captured demographic variables (age and sex) and health status indicators, including body mass index (BMI), fasting plasma glucose (FPG), hemoglobin concentration, smoking history, prior radiotherapy, and comorbidities (hypertension and diabetes mellitus). (2) Clinical and Stoma-Related Data Collection Form: This form documented stoma characteristics, including stoma type (end vs. loop), construction method, stoma shape, height above skin level, use of a support rod, preoperative stoma site marking, presence of peristomal skin folds, and co-location of surgical wounds within the baseplate adhesive area. Continuity of care after discharge was also recorded. (3) Ostomy Self-

Care Ability Assessment Scale (OSCAAS): A validated tool adapted from Kearney and Fleischer (1979) [13] was used to evaluate patients' capacity for autonomous stoma management. The scale consists of 43 items across four dimensions: health knowledge, self-care skills, sense of responsibility, and self-concept. Each item is scored from 0 to 4, yielding a total score of 0–172. Patients were classified as having high (>66% of the total score), moderate (33–66%), or low (<33%) self-care ability based on their overall scores.

All instruments were developed with reference to established diagnostic criteria for PMASD, national and international best practices, and peer-reviewed literature [14]. In our cohort, the internal consistency for the OSCAAS was acceptable (Cronbach's α = 0.84), and the content validity assessed by two stoma nurses and one colorectal surgeon was high (content validity index [CVI] = 0.90). Prior to implementation, content validity was confirmed through an expert panel review, and data collectors received standardized training to support measurement reliability.

Assessment of Peristomal Moisture-Associated Skin Damage

The diagnosis of PMASD was guided by consensus criteria informed by the Skin Moisture Alert Reporting Tool (SMART) [15] and expert recommendations from the World Council of Enterostomal Therapists [16]. SMART was used solely for preliminary risk identification and not as a formal diagnostic instrument. PMASD was defined as inflammation or erosion of the peristomal skin attributable to prolonged exposure to moisture from endogenous sources (e.g., fecal effluent, sweat, and wound exudate) or exogenous sources (e.g., bathing water).

The diagnostic criteria included the following: patient-reported symptoms (pain, pruritus, or burning) localized to the peristomal area; clinical signs of moisture-related skin injury, typically irregular erythematous lesions, blistering, epidermal stripping, or superficial erosion in areas directly exposed to moisture; and recurrent detachment of the ostomy appliance necessitating unplanned changes, with visible contamination of the baseplate corresponding to the zone of skin damage upon removal.

An interdisciplinary assessment team composed of five experienced clinicians (a certified stoma care nurse, a geriatric nursing specialist, a senior ward nurse, a colorectal surgeon, and the department chief) independently evaluated each case. The team members had 10–30 years of clinical experience. Assessments were conducted during index hospitalization and at 1, 2, and 3 months postoperatively, as well as when patients reported new symptoms. In instances of disagreement, final determinations were reached by consensus following a team discussion.

Data Management and Statistical Analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA) and R, version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were assessed for normality using the Shapiro–Wilk test. Normally distributed variables are presented as mean $\pm$ standard deviation (SD) and were compared using independent-samples *t* tests; non-normally distributed variables are presented as median and interquartile range (IQR) and were compared using the Mann–Whitney *U* test. Categorical variables are reported as frequencies (%) and were compared using the χ^2 test or Fisher's exact test, as appropriate.

Candidate predictors were first examined using univariate analyses, and variables with statistical significance ($p <$ 0.05) were entered into a multivariable binary logistic regression model. The variable selection used a backward stepwise likelihood-ratio procedure to derive the final predictive model. The results were reported as adjusted odds ratios (ORs) with 95% confidence intervals (CIs) and corresponding regression coefficients (β).

The model performance was evaluated in terms of discrimination, calibration, and clinical utility. Discrimination was quantified using the area under the receiver operating characteristic curve (AUC). Calibration was assessed using the Hosmer–Lemeshow goodness-of-fit test. A predictive nomogram was constructed using the rms package in R to facilitate individualized risk estimation. Internal model stability was assessed using bootstrap resampling (1000 iterations) on the development cohort (2021–2022). Additionally, temporal validation was conducted using an independent cohort of 68 consecutive patients from 2023 to evaluate the model's generalizability. All statistical tests were two-sided, and $p < 0.05$ was considered statistically significant.

Results

Study Population

A total of 275 older adults who underwent enterostomy were initially enrolled. After excluding 45 patients due to missing data, 230 participants were included in the final analysis. Of these, 162 patients comprised the model-development cohort used to build the risk-prediction model, and the remaining 68 formed the temporal validation cohort. The overall study population included 135 males and 95 females, with ages ranging from 65 to 93 years (mean $\pm$ SD, 73.79 $\pm$ 7.19 years). A comparison of baseline characteristics between the model-development cohort (n = 162) and the temporal validation cohort (n = 68) showed no statistically significant differences in key demographic, clinical, and stoma-related variables (all $p > 0.05$), supporting the comparability of the two cohorts for temporal validation (Table 1).

Table 1. Comparison of baseline characteristics between the model-development and temporal validation cohorts.

Characteristic	Model group (n = 162)	Temporal validation group (n = 68)	Statistic	p
Age (years)	73.5 ± 7.1	73.8 ± 7.3	t = –0.28	0.782
Sex (Male)	95 (58.6%)	40 (58.8%)	χ^2 = 0.00	0.976
BMI (kg/m^2)	23.2 ± 3.2	23.0 ± 3.3	t = 0.42	0.673
Smoking history	66 (40.7%)	28 (41.2%)	χ^2 = 0.00	0.949
History of hypertension	85 (52.5%)	35 (51.5%)	χ^2 = 0.02	0.888
History of diabetes	50 (30.9%)	22 (32.4%)	χ^2 = 0.05	0.823
History of radiotherapy	60 (37.0%)	25 (36.8%)	χ^2 = 0.00	0.974
Stoma method (Loop stoma)	51 (31.5%)	21 (30.9%)	χ^2 = 0.01	0.930
Stoma type (Ileostomy)	106 (65.4%)	47 (69.1%)	χ^2 = 0.30	0.582
Stoma shape (Oval)	75 (46.3%)	31 (45.6%)	χ^2 = 0.01	0.920
Stoma height (cm)	1.35 (0.85, 1.60)	1.30 (0.80, 1.55)	Z = 0.65	0.518
Preoperative stoma marking (No)	109 (67.3%)	45 (66.2%)	χ^2 = 0.03	0.867
Stoma reinforcing bar (Yes)	73 (45.1%)	29 (42.6%)	χ^2 = 0.11	0.740
Surgical incision in baseplate area (Yes)	43 (26.5%)	17 (25.0%)	χ^2 = 0.06	0.811
Skin folds around the stoma (Yes)	67 (41.4%)	27 (39.7%)	χ^2 = 0.05	0.819
Hemoglobin levels (g/L)	125.3 ± 14.7	124.1 ± 15.0	t = 0.58	0.565
Fasting plasma glucose (Above normal)	48 (29.6%)	20 (29.4%)	χ^2 = 0.00	0.974
Bowel regularity (No)	74 (45.7%)	30 (44.1%)	χ^2 = 0.05	0.827
Stoma self-care ability (Low)	58 (35.8%)	24 (35.3%)	χ^2 = 0.01	0.940
Continuing care (No)	97 (59.9%)	41 (60.3%)	χ^2 = 0.00	0.954

BMI, body mass index.

Univariate Analysis of Peristomal Moisture-Associated Skin Damage

The patients were classified into two groups based on their clinical outcomes: those who developed postoperative PMASD (observation group) and those who did not (control group). Among the 162 patients in the model-development cohort, 69 (42.59%) developed PMASD. There were no statistically significant differences between the groups in age, sex, BMI, smoking history, history of hypertension or diabetes mellitus, stoma construction method, stoma shape, or hemoglobin level (all $p > 0.05$). In contrast, significant between-group differences were observed for FPG, preoperative stoma site marking, stoma height, type of stoma (ileostomy vs. colostomy), use of a stoma reinforcing bar, presence of skin folds around the stoma, presence of a surgical incision within the baseplate adhesive area, history of radiotherapy, bowel regularity, stoma self-care ability, and continuity of care after discharge (all $p < 0.05$). The detailed results are listed in Table 2.

Development and Predictive Performance of the Risk-Prediction Model for PMASD

Predictors demonstrating statistical significance in univariate analysis (FPG, preoperative stoma marking, stoma height, ileostomy, stoma reinforcement bar, skin folds around the stoma, surgical incision in the baseplate area, history of radiotherapy, bowel regularity, stoma self-care ability, and continuity of care) were incorporated as candidate independent variables into a multivariate binary logistic regression model. Variable coding (including reference categories) is detailed in Table 3. For the continuous predictor ”stoma height”, receiver operating characteristic (ROC) analysis in the development cohort determined the decision threshold for PMASD prediction; a cutoff value of <1.30 cm was established and directly applied in the validation cohort. Although dichotomising continuous variables may reduce information content and introduce potential bias, this threshold was chosen to enhance clinical interpretability and facilitate application in bedside risk assessment. The outcome variable (PMASD) was coded as 0 (no skin damage) and 1 (skin damage). The final model was constructed using backward stepwise selection based on likelihood ratio tests (exclusion criterion $p > 0.05$). The multivariate model retained seven independent predictors (Table 3).

The results indicated that the presence of surgical incisions in the baseplate area (OR = 4.80; 95% CI, 1.04–7.51), stoma type (OR = 3.49; 95% CI, 1.27–7.99), history of radiotherapy (OR = 1.49; 95% CI, 1.05–2.10), lack of preoperative stoma marking (OR = 5.07; 95% CI, 2.50–8.30), and skin folds around the stoma (OR = 3.96; 95% CI, 2.53–16.10) were identified as independent risk factors for PMASD. Conversely, a stoma height of ≥1.30 cm (OR = 0.11; 95% CI, 0.04–0.29) and continuity of care (OR = 0.60; 95% CI, 0.45–0.80) were protective factors against PMASD, as shown in Table 4. The final risk-prediction model for moisture-associated skin damage around the enterostomy in older patients is expressed as: Z = –1.43 – (2.21 × stoma height) + (1.57 × a surgical incisions in the adhesive area of the baseplate) + (1.25 × ileostomy) + (0.40 × history of

Table 2. Comparison of clinical characteristics between PMASD and non-PMASD groups.

Predictor variables	Non-PMASD Groups (n = 93)	PMASD Groups (n = 69)	Statistic	*p*
Age (years)	73.20 ± 6.80	74.60 ± 7.50	$t = -1.24$	0.217
Sex			$\chi^2 = 0.38$	0.538
Male	57 (61.29)	38 (55.07)		
Female	36 (38.71)	31 (44.93)		
BMI (kg/m^2)	23.3 0 ± 3.10	22.90 ± 3.40	$t = 0.78$	0.436
Smoking history			$\chi^2 = 0.72$	0.396
No	58 (62.37)	38 (55.07)		
Yes	35 (37.63)	31 (44.93)		
History of hypertension			$\chi^2 = 0.29$	0.591
No	42 (45.16)	34 (49.28)		
Yes	51 (54.84)	35 (50.72)		
History of diabetes			$\chi^2 = 0.21$	0.646
No	63 (67.74)	49 (71.01)		
Yes	30 (32.26)	20 (28.99)		
Stoma method			$\chi^2 = 1.17$	0.279
End stoma	67 (72.04)	44 (63.77)		
Loop stoma	26 (27.96)	25 (36.23)		
Stoma shape			$\chi^2 = 0.52$	0.470
Round	52 (55.91)	35 (50.72)		
Oval	41 (44.09)	34 (49.27)		
Hemoglobin levels (g/L)	126.30 ± 14.20	123.8 ± 15.6	$t = 1.05$	0.295
Stoma height (cm)	1.60 (0.90, 1.70)	0.90 (0.60, 1.10)	Z = –4.10	<0.001
A surgical incision in the stoma baseplate area			$\chi^2 = 20.83$	<0.001
No	81 (87.10)	38 (55.07)		
Yes	12 (12.90)	31 (44.93)		
Type of stoma			$\chi^2 = 8.75$	0.003
Colostomy	41 (44.09)	15 (21.74)		
Ileostomy	52 (55.91)	54 (78.26)		
History of radiotherapy			$\chi^2 = 19.57$	<0.001
No	72 (77.42)	30 (43.48)		
Yes	21 (22.58)	39 (56.52)		
Preoperative stoma marking			$\chi^2 = 12.82$	<0.001
No	52 (55.91)	57 (82.61)		
Yes	41 (44.09)	12 (17.39)		
Skin folds around the stoma			$\chi^2 = 28.21$	<0.001
No	71 (76.34)	24 (34.78)		
Yes	22 (23.66)	45 (65.22)		
Continuing care			$\chi^2 = 26.20$	<0.001
No	47 (50.54)	50 (72.46)		
Yes	46 (49.46)	19 (27.54)		
Bowel regularity			$\chi^2 = 13.41$	<0.001
No	31 (33.33)	43 (62.32)		
Yes	62 (66.67)	26 (37.68)		
Fasting plasma glucose			$\chi^2 = 22.46$	<0.001
Normal	71 (76.34)	43 (62.32)		
Above normal levels	22 (23.66)	26 (37.68)		
Stoma reinforcing bar			$\chi^2 = 14.46$	<0.001
No	63 (67.74)	26 (37.68)		
Yes	30 (32.26)	43 (62.32)		
Stoma self-care ability			$\chi^2 = 23.78$	<0.001
Low level	28 (30.11)	30 (43.48)		
Moderate or high level	65 (69.89)	39 (56.52)		

PMASD, peristomal moisture-associated skin damage.

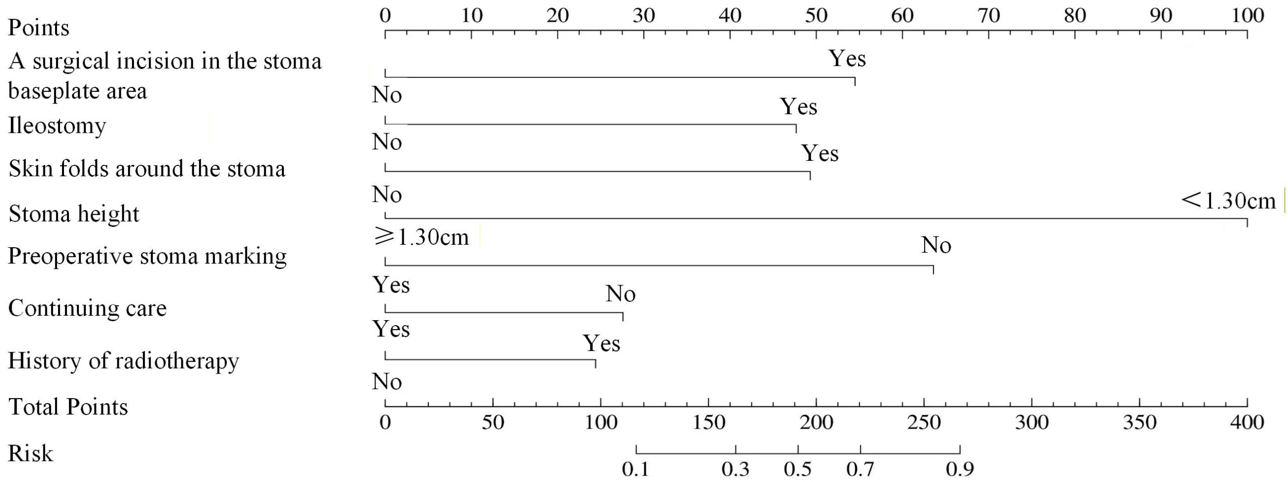

Fig. 1. Nomogram for PMASD risk prediction in older adults with enterostomies. PMASD, peristomal moisture-associated skin damage.

Table 3. Variable assignment table.

Predictor variables	Assignment
Stoma height (cm)	0 if ≥1.3 cm, 1 if <1.3 cm
A surgical incision in the stoma baseplate area	0 if No, 1 if Yes
Type of stoma	0 if Colostomy, 1 if Ileostomy
History of radiotherapy	0 if No, 1 if Yes
Preoperative stoma marking	0 if Yes, 1 if No
Skin folds around the stoma	0 if No, 1 if Yes
Continuing care	0 if Yes, 1 if No
Bowel regularity	0 if Yes, 1 if No
Fasting plasma glucose	0 if Normal, 1 if Above normal levels
Stoma reinforcing bar	0 if No, 1 if Yes
Stoma self-care ability	0 if moderate or high level, 1 if low level

Table 4. Logistic regression analysis of moisture-associated skin damage around the enterostomy.

Predictor variables	β	SE	Wald χ^2	p	OR (95% CI)
constant	–1.43	0.51	–2.40	0.017	0.24 (0.14–0.35)
Stoma height (cm)	–2.21	0.46	–4.57	<0.001	0.11 (0.04–0.29)
A surgical incision in the stoma baseplate area	1.57	0.48	2.04	<0.001	4.80 (1.04–7.51)
Ileostomy	1.25	0.47	2.48	0.013	3.49 (1.27–7.99)
History of radiotherapy	0.40	0.49	2.29	0.002	1.49 (1.05–2.10)
Preoperative stoma marking	1.62	0.48	11.37	0.005	5.07 (2.50–8.30)
Skin folds around the stoma	1.38	0.47	3.92	<0.001	3.96 (2.53–16.10)
Continuing care	–0.51	0.45	–1.13	0.011	0.60 (0.45–0.80)

SE, standard error; OR, odds ratio; CI, confidence interval.

radiotherapy) + (1.62 × no preoperative stoma marking) + (1.38 × presence of skin folds around the stoma) – (0.51 × continuity of care), with the predicted probability given by P = 1/(1 + exp[–Z]).

Fig. 1 shows the nomogram of the predictive model. Using the scoring scale in each row, the point value for each risk factor in the model can be determined. Subsequently, the points can be summed for each older patient to obtain a total score, and the corresponding risk probability can be located in the last row of the nomogram. For a 72-year-old patient with an ileostomy, stoma height of 0.8 cm, and skin folds, the total score is 198 points, and the predicted 30-day PMASD risk is 55%. The Hosmer–Lemeshow test for the predictive model yielded p = 0.851, indicating a good fit. The overall accuracy of the model was 0.830. The optimal cut-off value for the prediction model was determined using the maximum Youden index. The AUC was 0.90 [95% CI 0.86–0.95], indicating good discriminative ability. The ROC curve is shown in Fig. 2. The Youden index for this ROC curve was 0.66, with a sensitivity of 0.850 and specificity of 0.810. Fig. 3 shows the calibration plot of the predictive model. The calibration curve was closely aligned with the ideal line, with a calibration intercept of –0.02, a slope of 0.98, and a calibration error of 0.027, suggesting that the predicted probability of PMASD closely matched the observed probability, demonstrating good consistency.

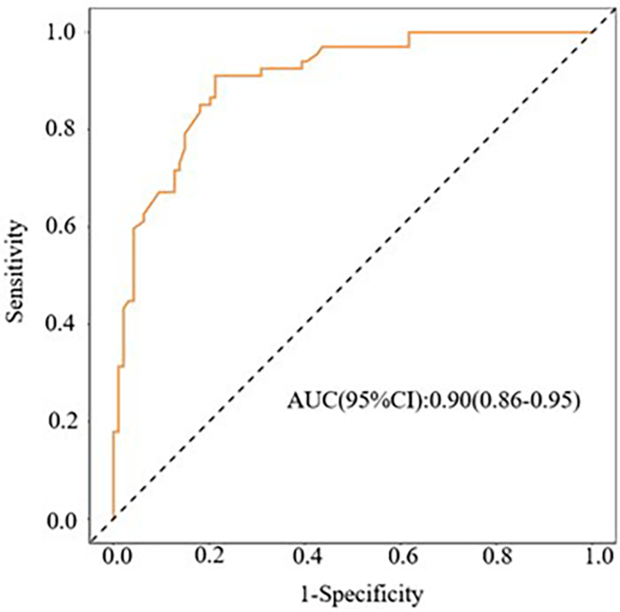

Fig. 2. The ROC curves of the risk-prediction model. AUC, area under the receiver operating characteristic curve; CI, confidence interval; ROC, receiver operating characteristic.

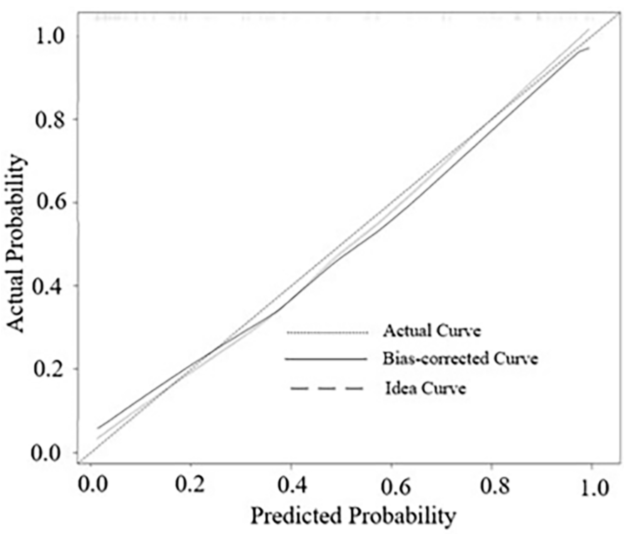

Fig. 3. The calibration curves of the risk-prediction model.

Time-Split Validation of the PMASD Risk-Prediction Model

Within the time-validated cohort (n = 68), 28 patients (41.18%) developed PMASD. The model demonstrated a sensitivity of 0.857 (24/28) and a specificity of 0.800 (32/40), indicating favourable predictive performance in an independent cohort. The overall accuracy of the model in this time-split validation was 82.35%, indicating good clinical predictive performance. The AUC for the time-split validation was 0.91 [95% CI 0.84–0.98]. The ROC curves are presented in Fig. 4. The Hosmer–Lemeshow test yielded p = 0.875, indicating a good model fit. Using the maximum Youden index as the optimal cut-off, the Youden index was 0.703, with a sensitivity of 0.828 and a specificity of 0.875. Fig. 5 presents the calibration plot for the time-split validation. The calibration curve was closely aligned with the ideal curve, with a calibration error of 0.013, demonstrating that the model's predicted probability of PMASD was consistent with the observed probability, confirming the model's strong predictive accuracy in an external clinical setting.

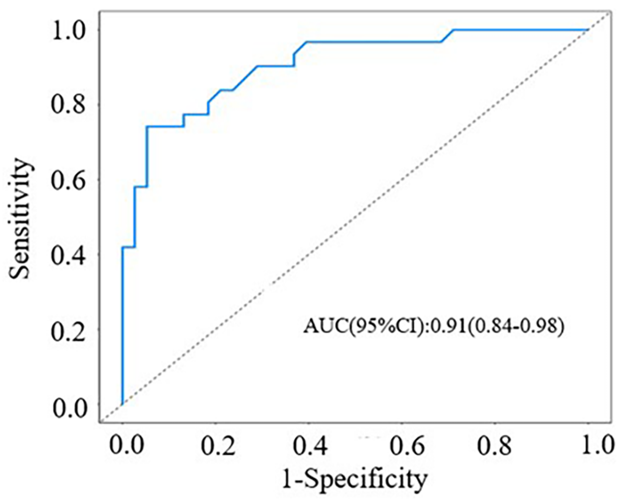

Fig. 4. The ROC curves of the risk-prediction model for the validation group. Validation cohort: n = 68, event rate 41.2%; cut-off 0.34 (Youden index from training set); DeLong p = 0.72 versus internal AUC.

The decision curve analysis (DCA) data for the risk-prediction model for PMASD is shown in Fig. 6. The x-axis represents the threshold probability, and the y-axis represents the net benefit rate (benefits minus harms). The solid black line and solid gray line represent two extreme scenarios: the solid black line assumes that no patients developed PMASD and no interventions were provided, yielding a net benefit rate of 0; the solid gray line assumes that all patients developed skin damage and received interventions, producing a downward-sloping net benefit. The blue line represents the net benefit rate based on the prediction model developed in this study. The DCA data show that

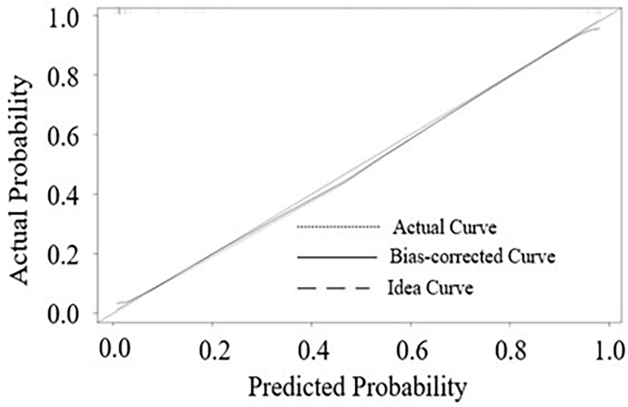

Fig. 5. The calibration curves of the risk-prediction model for the validation group.

the blue line representing our model does not align with the two extreme lines and is positioned closer to the upper-right corner, indicating that the model has good clinical utility.

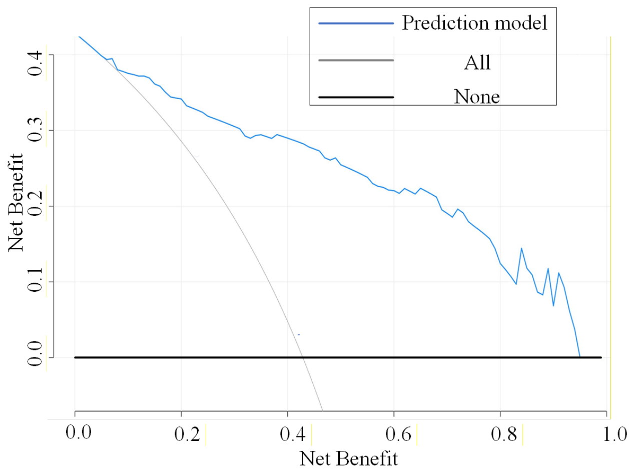

Fig. 6. DCA curve of the model for predicting PMASD. DCA, decision curve analysis.

Discussion

This study identified several independent risk factors for PMASD in older patients undergoing enterostomy, including the presence of a surgical incision in the baseplate area, ileostomy, history of radiotherapy, absence of preoperative stoma marking, and peristomal skin folds. Protective factors included stoma height ≥1.30 cm and continuity of care. Using these variables, we developed a risk-prediction model for PMASD in this population. The model demonstrated excellent discriminatory power (AUC=0.900), suggesting high predictive accuracy on this dataset. The derived nomogram enables visual evaluation and is convenient for clinical application, helping to identify patients at high risk for PMASD and to guide targeted prevention and timely intervention to improve outcomes.

In this study, older patients with a history of preoperative radiotherapy were at a higher risk of developing PMASD. Older patients generally have more sensitive skin that reacts more intensely to internal and external stimuli. The skin in irradiated areas is particularly susceptible to redness, itching, blistering, and cracking. If the peristomal skin lies within the irradiated area, it becomes more vulnerable to PMASD due to the combined effects of radiation-induced damage and irritation from stoma effluent. Additionally, radiotherapy can induce gastrointestinal complications in older patients, leading to irregular bowel movements, such as diarrhea or constipation. These conditions increase the likelihood of stoma bag leakage, contamination, and peristomal swelling, further increasing the risk of skin damage [17]. To address this risk, we recommend establishing an interdisciplinary intervention team comprising stoma care nurses and geriatric specialist nurses. This team should focus on enhancing patient education regarding stoma-related complications and risks associated with preoperative radiotherapy. Older patients with colorectal cancer and stomas should be informed about potential dermatological and gastrointestinal complications associated with radiotherapy, allowing them to anticipate and manage symptoms effectively. Furthermore, the frequency of adjuvant radiotherapy sessions should be adjusted based on the patient's specific condition to minimize the risk of complications [18].

The results of this study indicate that the risk of developing PMASD was 3.96 times higher in patients with peristomal skin folds than in those without, and 4.80 times higher in patients with surgical incisions in the stoma baseplate area than in those without such incisions. Skin folds and surgical wounds within the baseplate adhesive area can compromise secure attachment and increase the risk of leakage. In such cases, stoma care becomes more challenging because it requires balancing secure baseplate attachment with the maintenance of wound sterility and appropriate dressing management. Uneven skin surfaces and wound exudates can impair baseplate adhesion, resulting in leakage that may lead to wound contamination or infection. These complications can delay wound healing, exacerbate baseplate leakage, and create a vicious cycle of persistent peristomal skin damage. Older patients often have dry and atrophic skin with reduced elasticity, which can contribute to the development of skin folds. To address this, caregivers could gently stretch the skin to flatten it before applying a stoma bag. An anti-leak paste can be used to fill deeper folds, creating a relatively flat surface for improved adhesion. If the stoma is located near the navel or groin, where the baseplate edges may adhere poorly, trimming the baseplate edges can help avoid gaps and ensure an adequate adhesive area. In addition, elastic adhesive strips can be used to reinforce edges for improved adherence. For patients with surgical incisions in the stoma baseplate area, special dressings, such as hydrocolloid or alginate, should be applied under the guidance of a healthcare professional. These dressings can isolate stoma effluent, prevent wound contamination, promote wound healing, and create a flat, clean, and dry surface for baseplate adhesion. This reduces the risk of baseplate leakage and subsequently lowers the incidence of PMASD [19].

In this study, the absence of preoperative stoma site markings was a significant risk factor for PMASD in older patients. This finding is consistent with that of Kim *et al*. [20], who reported a higher risk of PMASD in patients without preoperative stoma marking compared with those who were marked. Stelton *et al*. [16] recommend that preoperative stoma site marking be performed by trained professionals in collaboration with the surgeon to avoid scars, skin folds, and bony prominences and to ensure optimal site selection. However, prior research indicates that only 38–61.96% of patients undergo preoperative stoma site marking [21]. Enhanced collaboration between medical and nursing staff and improved training in preoperative stoma site marking are therefore strongly recommended. Increasing awareness among healthcare providers regarding the importance of preoperative stoma site marking can promote and standardize its implementation, ultimately reducing the incidence of PMASD in older patients undergoing enterostomy.

This study also found that older patients with low-lying stomas had a higher risk of developing PMASD than those with stomas protruding above the skin. A stoma height of $\geq$1.3 cm was identified as a protective factor. The ideal stoma height is 1–2 cm; when a mature stoma protrudes by at least 2 cm, the risk of leakage is significantly reduced. Patients should monitor the stoma height at each stoma bag change. If the height falls below 1 cm or is too low for smooth fecal flow, a convex baseplate with a belt, under stoma care guidance, can help elevate the stoma by pressing down the surrounding skin. This approach improves adhesion, thereby reducing leakage and the risk of PMASD.

The results indicate that the risk of PMASD is 3.49 times higher in patients with an ileostomy than in patients without an ileostomy, consistent with findings by Nybaek H [17]. This increased risk may be due to the anatomical and physiological characteristics of the ileum: it is richly vascularized, has a thinner wall, and produces more liquid effluent with a higher pH than normal skin, making it more irritating to the peristomal area. Additionally, older patients with an ileostomy typically have a higher stool output that is watery or mushy and contains digestive enzymes, further contributing to PMASD. Loop ileostomies often require a stoma support rod, which complicates baseplate adhesion. The presence of rods can necessitate oversized baseplate openings, increasing skin exposure to feces and raising the risk of PMASD. For older patients with an ileostomy, baseplates with greater erosion resistance are recommended when the output is high or the adhesive barrier dissolves quickly. Patients should be advised to remove the support rod within 2–4 weeks to avoid prolonged retention due to concerns about stoma retraction.

Older patients with enterostomies often experience self-care challenges after discharge because of the lack of timely guidance from professional caregivers. In this study, continuity-of-care interventions were implemented through hospital phone calls, WeChat follow-ups, and stoma support group meetings. These interventions aimed to educate patients about stoma bag replacement, peristomal skin care, the prevention of stoma complications, and psychosocial support. The results indicated that continuity of care was a protective factor against PMASD in older patients undergoing enterostomies (OR = 0.60). During the continuity-of-care period, professional caregivers can address care-related concerns, correct improper self-care practices, and help eliminate harmful lifestyle habits, thereby enhancing self-care abilities. This approach enables patients to establish effective self-management systems and personalized health education plans, ensuring comprehensive and structured post-discharge care. By providing consistent guidance and tailored interventions at every stage after discharge, continuity of care optimizes physical, psychological, and social well-being, improves quality of life, and reduces the incidence of PMASD [22].

This study had some limitations. First, it was limited to older patients with enterostomies from a single hospital, which may introduce selection bias and limit the generalizability of the findings. Second, although temporal validation enhances the clinical relevance of our prediction model, the use of a timeseries split for model validation, while methodologically sound for retrospective data, may be influenced by temporal shifts in clinical practice. These unmeasured temporal factors might affect the model's direct comparability and extrapolation to other settings or future patient populations. Therefore, external validation across multiple centers and time periods is warranted to confirm the robustness and generalizability of our model before its widespread clinical implementation. Third, the study primarily focused on identifying risk factors and developing a predictive model, without evaluating the effectiveness of interventions or validating outcomes through interventional research. Fourth, regarding model validation, our study employed a temporal validation approach (using data from 2023), which, while strengthening the assessment of model performance over time, must be considered a form of internal validation because it utilized data from the same single center. The absence of validation using truly independent, multicenter, or externally sourced cohorts limits the direct generalizability of our findings to other healthcare settings. Therefore, external validation across multiple institutions and diverse populations remains necessary before any widespread clinical application can be recommended. Finally, although backward stepwise linear regression was chosen for its transparency and clinical interpretability, we acknowledge that penalized methods (e.g., Least Absolute Shrinkage and Selection Operator (LASSO)) may further reduce over-fitting. Future work with larger datasets will explore LASSO/Elastic Net to confirm the present predictor set and quantify coefficient shrinkage.

Conclusions

This study indicates that, in older patients with enterostomies, preoperative radiotherapy, peristomal skin folds, the presence of a surgical incision in the stoma baseplate area, absence of preoperative stoma site marking, low stoma height, and lack of continuity of care are significant risk factors for PMASD. The PMASD risk-prediction model developed in this study was validated and demonstrated strong predictive performance. This model can serve as a clinical tool for healthcare providers to identify high-risk patients and implement timely, targeted interventions to prevent PMASD. However, the excellent performance of the model should be interpreted with caution as all the data are from the same centre. Further validation across multiple hospitals with larger sample sizes is required to strengthen the generalizability and clinical applicability of these findings.

Availability of Data and Materials

The data used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

This study was conducted in collaboration with all authors. LFC: conceptualisation, literature review, methodology, data collection, data analysis and manuscript writing. LXL: data collection, data analysis and supervision. YYC: conceptualisation, literature review and methodology. JFC: conceptualisation, methodology and manuscript writing. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study protocol was reviewed and approved by the Institutional Ethics Committee of The Fifth Affiliated Hospital of Wenzhou Medical University (Approval No. 2022-321). Written informed consent was obtained from all participants prior to enrollment. Confidentiality of personal and medical information was strictly maintained throughout the study period in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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