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*Original Article*

# A nomogram for predicting incontinence-associated dermatitis in Chinese patients with severe acute pancreatitis: a retrospective analysis

Qian Feng, Heyu Chen, Aiping Du, Yu Xu, Huan Liu

*Department of Critical Care Medicine, West China Hospital, Sichuan University/West China School of Nursing, Sichuan University, Chengdu 610041, Sichuan, China*

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**Abstract:** Objective: To identify the incidence of and risk factors for incontinence-associated dermatitis (IAD) among Chinese patients with severe acute pancreatitis (SAP) to facilitate the development of a predictive risk assessment model. Methods: A prediction model was constructed using data from 302 SAP patients treated at West China Hospital, Sichuan University, from January 2020 to December 2022. The dataset was divided into training (n=183), testing (n=79), and external validation (n=40) sets. Predictors for incontinence-associated dermatitis were identified through univariate and multivariate logistic regression analyses. A nomogram was established to predict the occurrence of incontinence-associated dermatitis. Receiver operating characteristic (ROC) curves and the Hosmer-Lemeshow test were used to evaluate the model's performance. Results: A total of 302 SAP patients showed a 57% incidence of IAD. Independent predictors included acute physiology and chronic health evaluation II scores of 15 or higher, fecal incontinence, stool frequency greater than 3 times per day, watery stool, and the use of herbal enemas. In the training set, the model showed an area under the ROC curve (AUC) of 0.836 (95% CI: 0.779-0.894), with sensitivity and specificity values of 86.5% and 66.7%, respectively. The testing set yielded an AUC of 0.825 (95% CI: 0.728-0.921), with sensitivity of 82.0% and specificity of 72.4%. External validation using an independent dataset produced an AUC of 0.788 (95% CI: 0.644-0.933), with a sensitivity of 92.9% and a specificity of 57.7%. Conclusion: The nomogram provides a simple and accurate tool for the prompt identification of patients with incontinence-associated dermatitis.

**Keywords:** Dermatitis, nomograms, pancreatitis, risk factors

## Introduction

Incontinence-associated dermatitis (IAD) refers to inflammation of the skin that results from prolonged, frequent exposure to feces and/or urine [1, 2]. Symptoms characteristic of IAD primarily manifest in the groin, perineum, and buttocks and consist of erythema and edema of the stratum corneum together with plasma oozing, vesicles, and secondary skin infections in some cases [3]. Patients admitted to the intensive care unit (ICU) face high rates of incontinence, placing them at risk of IAD [4, 5], which affects an estimated 6.89%-50% of these patients [5]. IAD tends to cause discomfort, pain, and the potential for infection as a result of skin barrier disruption while also exacerbating the risk and severity of pressure ulcer development [6]. These factors ultimately contribute to prolonged hospitalization, higher healthcare costs, and a greater workload for staff involved in critical care [7, 8].

Severe acute pancreatitis (SAP) is the most severe form of acute pancreatitis (AP). AP is a common gastrointestinal disease characterized by the activation of pancreatic enzymes for a variety of reasons, resulting in the release of a series of digestive enzymes that cause damage to local tissue and multi-organ syndrome [9]. SAP is an aggressive disease associated with high rates of morbidity, local and systemic complications, and mortality rates of up to 30% [10]. SAP-related deaths in ~80% of cases are related to infectious complications and multiorgan dysfunction, with pancreatic and peripan-

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creatic necrotic infections accounting for half of all infections, thus contributing substantially to SAP patient mortality [11].

Early SAP patient care centers on controlling infection and preventing worsening illness. Traditional Chinese medicine (TCM) treatment (such as herbal tube feeding, herbal enemas, and acupoint injections) is widely used for the effective management of SAP [12, 13], as it is often administered to patients in China who have not undergone surgery in combination with various Western medicines. These interventions can alleviate intra-abdominal pressure, intestinal edema, and serum amylase upregulation, thereby contributing to a reduction in symptom severity while also controlling SAP-related infection risk [14, 15]. These treatments, however, have laxative effects that can contribute to the incidence or worsening of incontinence. As critically ill patients, individuals with SAP appear to face a greater risk of IAD in clinical practice, complicating patient care and recovery. However, there appear to be no studies investigating this problem. As such, an understanding of the incidence of IAD and predicting the risk of IAD in patients with nonsurgical SAP would be invaluable as a means of improving patient management.

In some prior reports, researchers have developed predictive models for the assessment of IAD risk among individuals who are critically ill [16]. These models, however, are not specific or applicable to nonsurgical SAP patients, with few studies focused on this patient population. Moreover, the models do not consider specific factors involved in traditional Chinese medicine for the diagnosis of IAD. Therefore, the present study had two objectives. First, we evaluated the incidence of IAD in patients with SAP. The second objective was to identify risk factors for the development of IAD in SAP patients to design a predictive model. These findings lay the foundation for more effective prevention of IAD in hospitalized SAP patients.

## Methods

### *Research design*

The study was retrospective. The reporting of the study followed the guidelines of the Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis (TRIPOD) statement.

### *Setting and participants*

This study was conducted in West China Hospital, Sichuan University. In total, 4,432 patients were admitted to West China Hospital, Sichuan University, between January 2020 and December 2022. Inclusion Criteria: Patients who were eligible for enrollment were those ≥18 years old who had been diagnosed with SAP. Exclusion Criteria: Patients who had undergone SAP surgery, had IAD upon admission, were admitted for less than 24 hours, or lacked complete clinical data were excluded.

Studies have shown that a sample size of 10 times the number of predictors is necessary for logistic regression analysis [17]. The initial formulation of the predictors in this study was 24, which would require a sample size of at least 240 cases. Considering a 10% sample attrition rate, a minimum of 267 participants would thus be needed. This study was approved by the Ethics Committee of West China Hospital, Sichuan University.

### *Data collection*

The data were accessed between January and April 2023. A data collection sheet was developed on relevant publications [18, 19], after which this sheet was further revised through group discussion and consultation with experts. This sheet included five sections designed for collection: (1) basic demographic characteristics, including age, sex, underlying disease, and body mass index (BMI); (2) disease-related characteristics, including scores on relevant scales on the day of admission (e.g., the Activities of Daily Living Scale [ADL] score, Nutrition Risk Screening 2002 [NRS2002] score, Acute Physiology and Chronic Health Evaluation II [APACHE II] score and Braden scale score), serum ALB level, and maximum body temperature; (3) treatment-related characteristics, including mechanical ventilation, sedation, vasoactive drug use, antibiotic administration, gastrointestinal stimulation, herbal tube feeding use, herbal enema use, acupoint injection, and enteral nutrition; (4) incontinence type (fecal and/or urinary); and (5) occurrence (or not) of IAD. Data for the first three sections were collected within three days of admission. If more than one piece of data exists (such as temperature may be taken six times a day), the worst one is selected. Data from the last two components can be collected throughout the stay in the ICU. All the data were collected by four senior nurses from the comprehensive ICU with >5 years of ICU experience and extensive experience caring for stomas and wounds. These nurses were trained in the use of the collection sheet and the detection of IAD prior to the execution of this study by an international stoma and wound therapist and an ostomy therapist. IAD incidence was the primary outcome variable for these analyses, with relevant descriptors having been obtained by reviewing the hospital's electronic medical records together with the results of joint assessments from two nurses. Electronic medical records were also used to obtain other relevant data, including basic characteristics, disease-related conditions, and treatment approaches. When the data were ambiguous, the relevant patient records were reviewed again, and any sheet still containing issues was eliminated to ensure that the resulting data were accurate.

*Statistical analysis*

The data were analyzed with SPSS 24.0. Normally distributed and skewed data are presented as the means ± standard deviations (SDs) and medians (interquartile ranges), respectively, and were compared with t tests or rank-sum tests. Categorical variables are represented as frequencies and percentages and were compared with $\chi^2$ tests or Fisher's exact test. Independent predictors related to IAD among patients with SAP were identified through logistic regression analyses, with $P<0.05$ set as the significance threshold. A predictive model was developed and visualized via R version 4.3.1 to construct nomogram plots, with the consistency index (C-index) then used to assess model predictive performance. Internal validation through bootstrapping was also used to generate calibration curves. Model fit was assessed with the Hosmer-Lemeshow test, and the receiver operating characteristic (ROC) curve was generated and the area under the curve (AUC) was calculated.

## Results

*General characteristics of patients*

The electronic medical records of the comprehensive ICU were searched for data from 369 patients with a first diagnosis of pancreatitis. Sixty-seven patients were excluded on the basis of the exclusion criteria described above, resulting in a final sample of 302 patients. The study flowchart for patient selection is illustrated in **Figure 1**. Among the 302 patients enrolled, 57.0% (n=172) developed IAD. The mean age of SAP patients was 48.83±14.30 years; 208 (68.9%) were males, and 94 (31.1%) were females. A minority of the patients with SAP had diabetes (9.3%) and hyperlipidemia (10.3%). The 302 enrolled patients were stratified into subsets according to their visit date. Data from 262 patients collected between January 2020 and June 2022 were randomly split into training and testing sets at a 7:3 ratio; baseline characteristics were balanced between groups (**Table 1**). An additional 40 patients seen from July to December 2022 served as an external validation set, independent of the training and testing procedures, to assess the model's generalizability.

*Univariate analyses*

In total, three SAP patients were admitted in critical condition such that BMI values could not be obtained, with these values being replaced via mean interpolation when these analyses were conducted. We ultimately identified 12 variables that differed significantly between the two patient groups in the training set, such as hyperlipidemia, BMI, APACHE II score, mechanical ventilation, use of sedation, acupoint injection, herbal tube feeding, herbal enema, enteral nutrition, fecal incontinence, stool frequency and stool consistency (**Table 2**).

*Multivariate analyses*

Next, logistic regression analyses were employed to determine which of the variables identified in the between-group comparison were independently associated with IAD via forward stepwise screening. Ultimately, five variables (i.e., APACHE II score, fecal incontinence, stool frequency, stool consistency, and herbal enema use) were identified as independent predictors (**Table 3**).

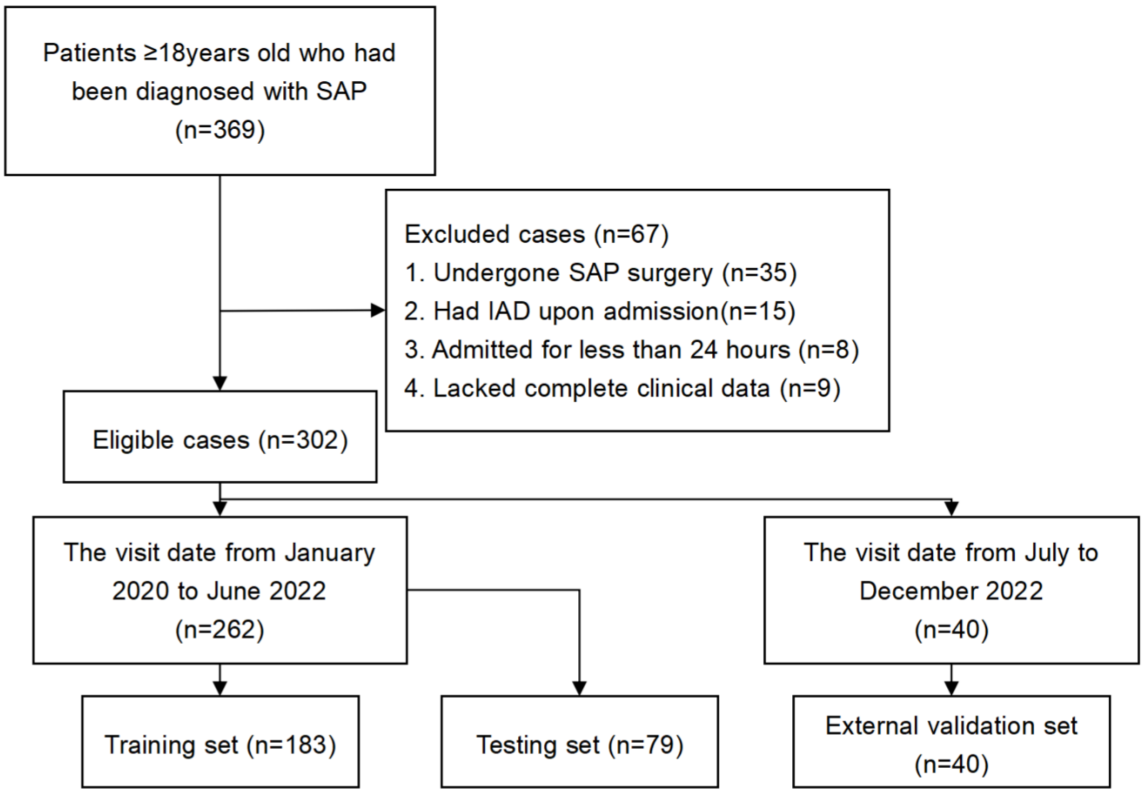


**Figure 1.** A study flow chart for patient selection. Abbreviations: SAP, severe acute pancreatitis; IAD, incontinence-associated dermatitis.

**Table 1.** Comparison of the training set and testing set data

| Variables | Total (n=262) | Training set (n=183) | Testing set (n=79) | Statistics | *P* value |
|---|---|---|---|---|---|
| Gender, n (%) | | | | 0.071 | 0.789 |
| Male | 176 (67.18) | 122 (66.67) | 54 (68.35) | | |
| Female | 86 (32.82) | 61 (33.33) | 25 (31.65) | | |
| Age, mean (SD) | 48.51±14.23 | 48.61±14.49 | 48.28±13.71 | 0.174 | 0.862 |
| Diabetes, n (%) | | | | 0.333 | 0.564 |
| Yes | 24 (9.16) | 18 (9.84) | 6 (7.59) | | |
| No | 238 (90.84) | 165 (90.16) | 73 (92.41) | | |
| Hyperlipidemia, n (%) | | | | 0.145 | 0.704 |
| Yes | 27 (10.31) | 18 (9.84) | 9 (11.39) | | |
| No | 235 (89.69) | 165 (90.16) | 70 (88.61) | | |
| BMI, mean (SD) | 26.05±3.97 | 25.90±3.81 | 26.40±4.33 | 0.941 | 0.348 |
| APACHE II score, n (%) | | | | 2.242 | 0.134 |
| <15 | 80 (30.53) | 61 (33.33) | 19 (24.05) | | |
| ≥15 | 182 (69.47) | 122 (66.67) | 60 (75.95) | | |
| ADL score, n (%) | | | | 2.200 | 0.138 |
| ≤40 | 257 (98.09) | 178 (97.27) | 79 (100.00) | | |
| >40 | 5 (1.91) | 5 (2.73) | 0 | | |
| NRS2002 score, n (%) | | | | 0.045 | 0.832 |
| <3 | 11 (4.20) | 8 (4.37) | 3 (3.80) | | |
| ≥3 | 251 (95.80) | 175 (95.63) | 76 (96.20) | | |

| | | | | | |
|---|---|---|---|---|---|
| Braden scale score, n (%) | | | | 0.842 | 0.359 |
| ≤12 | 205 (78.24) | 146 (79.78) | 59 (74.68) | | |
| >12 | 57 (21.76) | 37 (20.22) | 20 (25.32) | | |
| Serum albumin, n (%) | | | | 0.347 | 0.556 |
| <35 g/L | 224 (85.50) | 158 (86.34) | 66 (83.54) | | |
| ≥35 g/L | 38 (14.50) | 25 (13.66) | 13 (16.46) | | |
| Body temperature, n (%) | | | | 2.892 | 0.089 |
| ≤38.0°C | 137 (52.29) | 102 (55.74) | 35 (44.30) | | |
| >38°C | 125 (47.71) | 81 (44.26) | 44 (55.70) | | |
| Mechanical ventilation, n (%) | | | | 0.686 | 0.407 |
| Yes | 236 (90.08) | 163 (89.07) | 73 (92.41) | | |
| No | 26 (9.92) | 20 (10.93) | 6 (7.59) | | |
| Sedative, n (%) | | | | 0.138 | 0.711 |
| Yes | 195 (74.43) | 135 (73.77) | 60 (75.95) | | |
| No | 67 (25.57) | 48 (26.23) | 19 (24.05) | | |
| Number of antibiotics, mean (SD) | 2.33±1.30 | 2.33±1.29 | 2.34±1.34 | 0.079 | 0.937 |
| Gastrointestinal stimulant, n (%) | | | | 0.001 | 0.980 |
| Yes | 76 (29.01) | 53 (28.96) | 23 (29.11) | | |
| No | 186 (70.99) | 130 (71.04) | 56 (70.89) | | |
| Vasoactive agent, n (%) | | | | 1.794 | 0.180 |
| Yes | 113 (43.13) | 74 (40.44) | 39 (49.37) | | |
| No | 149 (56.87) | 109 (59.56) | 40 (50.63) | | |
| Acupoint injection, n (%) | | | | | |
| Yes | 122 (46.56) | 79 (43.17) | 43 (54.43) | 2.812 | 0.094 |
| No | 140 (53.44) | 104 (56.83) | 36 (45.57) | | |
| Herbal tube feeding, n (%) | | | | 0.368 | 0.544 |
| Yes | 150 (57.25) | 107 (58.47) | 43 (54.43) | | |
| No | 112 (42.75) | 76 (41.53) | 36 (45.57) | | |
| Herbal enema, n (%) | | | | 0.182 | 0.670 |
| Yes | 191 (72.90) | 132 (72.13) | 59 (74.68) | | |
| No | 71 (27.10) | 51 (27.87) | 20 (25.32) | | |
| Enteral nutrition, n (%) | | | | 0.012 | 0.913 |
| Yes | 128 (48.85) | 89 (48.63) | 39 (49.37) | | |
| No | 134 (51.15) | 94 (51.37) | 40 (50.63) | | |
| Fecal incontinence, n (%) | | | | 0.017 | 0.898 |
| Yes | 211 (80.53) | 147 (80.33) | 64 (81.01) | | |
| No | 51 (19.47) | 36 (19.67) | 15 (18.99) | | |
| Stool frequency, n (%) | | | | 3.027 | 0.082 |
| ≤3 per day | 176 (67.18) | 129 (70.49) | 47 (59.49) | | |
| >3 per day | 86 (32.82) | 54 (29.51) | 32 (40.51) | | |
| Stool consistency, n (%) | | | | 0.594 | 0.441 |
| Nonwatery stool | 178 (67.94) | 127 (69.40) | 51 (64.56) | | |
| Watery stool | 84 (32.06) | 56 (30.60) | 28 (35.44) | | |
| Urinary incontinence, n (%) | | | | 1.149 | 0.284 |
| Yes | 256 (97.71) | 180 (98.36) | 76 (96.20) | | |
| No | 6 (2.29) | 3 (1.64) | 3 (3.80) | | |

Abbreviations: IAD, incontinence-associated dermatitis; BMI, body mass index, calculated as weight in kilograms divided by height in meters squared; APACHE II, acute physiology and chronic health evaluation II; ADL, activities of daily living scale; NRS2002, nutrition risk screening 2002; SD, standard deviation.

**Table 2.** Comparison of patient characteristics between the two groups in the training set

| Variables | IAD (n=96) | Non-IAD (n=87) | Statistics | *P* value |
|---|---|---|---|---|
| Gender, n (%) | | | 2.465 | 0.116 |
| Male | 69 (71.87) | 53 (60.92) | | |
| Female | 27 (28.13) | 34 (39.08) | | |
| Age, mean (SD) | 48.54±13.36 | 48.69±15.72 | 0.069 | 0.945 |
| Diabetes, n (%) | | | 0.077 | 0.782 |
| Yes | 10 (10.42) | 8 (9.20) | | |
| No | 86 (89.58) | 79 (90.80) | | |
| Hyperlipidemia, n (%) | | | 5.131 | 0.023 |
| Yes | 14 (14.58) | 4 (4.60) | | |
| No | 82 (85.42) | 83 (95.40) | | |
| BMI, mean (SD) | 26.67±3.77 | 25.05±3.69 | 2.932 | 0.004 |
| APACHE II score, n (%) | | | 9.860 | 0.002 |
| <15 | 22 (22.92) | 39 (44.83) | | |
| ≥15 | 74 (77.08) | 48 (55.17) | | |
| ADL score, n (%) | | | 2.172 | 0.193 |
| ≤40 | 95 (98.96) | 83 (95.40) | | |
| >40 | 1 (1.04) | 4 (4.60) | | |
| NRS2002 score, n (%) | | | 2.529 | 0.153 |
| <3 | 2 (2.08) | 6 (6.90) | | |
| ≥3 | 94 (97.92) | 81 (93.10) | | |
| Braden scale score, n (%) | | | 0.911 | 0.340 |
| ≤12 | 74 (77.08) | 72 (82.76) | | |
| >12 | 22 (22.92) | 15 (17.24) | | |
| Serum albumin, n (%) | | | 0.231 | 0.631 |
| <35 g/L | 84 (87.50) | 74 (85.06) | | |
| ≥35 g/L | 12 (12.50) | 13 (14.94) | | |
| Body temperature, n (%) | | | 2.695 | 0.101 |
| ≤38.0°C | 48 (50.00) | 54 (62.07) | | |
| >38°C | 48 (50.00) | 33 (37.93) | | |
| Mechanical ventilation, n (%) | | | 12.633 | <0.001 |
| Yes | 93 (96.87) | 70 (80.46) | | |
| No | 3 (3.13) | 17 (19.54) | | |
| Sedative, n (%) | | | 5.838 | 0.016 |
| Yes | 78 (81.25) | 57 (65.52) | | |
| No | 18 (18.75) | 30 (34.48) | | |
| Number of antibiotics, mean (SD) | 2.46±1.29 | 2.18±1.29 | 1.438 | 0.152 |
| Gastrointestinal stimulant, n (%) | | | 0.069 | 0.793 |
| Yes | 27 (28.13) | 26 (29.89) | | |
| No | 69 (71.87) | 61 (70.11) | | |
| Vasoactive agent, n (%) | | | 0.723 | 0.395 |
| Yes | 36 (37.50) | 38 (43.68) | | |
| No | 60 (62.50) | 49 (56.32) | | |
| Acupoint injection, n (%) | | | 14.083 | <0.001 |
| Yes | 54 (56.25) | 25 (28.74) | | |
| No | 42 (43.75) | 62 (71.26) | | |
| Herbal tube feeding, n (%) | | | 14.943 | <0.001 |
| Yes | 69 (71.87) | 38 (43.68) | | |
| No | 27 (28.13) | 49 (56.32) | | |

| | | | | |
|---|---|---|---|---|
| Herbal enema, n (%) | | | 34.357 | <0.001 |
| Yes | 87 (90.62) | 45 (51.72) | | |
| No | 9 (9.38) | 42 (48.28) | | |
| Enteral nutrition, n (%) | | | 4.689 | 0.030 |
| Yes | 54 (56.25) | 35 (40.23) | | |
| No | 42 (43.75) | 52 (59.77) | | |
| Fecal incontinence, n (%) | | | 34.989 | <0.001 |
| Yes | 93 (96.87) | 54 (62.07) | | |
| No | 3 (3.13) | 33 (37.93) | | |
| Stool frequency, n (%) | | | 22.676 | <0.001 |
| ≤3 per day | 53 (55.21) | 76 (87.36) | | |
| >3 per day | 43 (44.79) | 11 (12.64) | | |
| Stool consistency, n (%) | | | 25.182 | <0.001 |
| Nonwatery stool | 51 (53.13) | 76 (87.36) | | |
| Watery stool | 45 (46.87) | 11 (12.64) | | |
| Urinary incontinence, n (%) | | | 3.366 | 0.105 |
| Yes | 96 (100.00) | 84 (96.55) | | |
| No | 0 | 3 (3.45) | | |

Abbreviations: IAD, incontinence-associated dermatitis; BMI, body mass index, calculated as weight in kilograms divided by height in meters squared; APACHE II, acute physiology and chronic health evaluation II; ADL, activities of daily living scale; NRS2002, nutrition risk screening 2002; SD, standard deviation.

**Table 3.** Results of the multivariate analyses

| Variables | Coefficient-*β* | SE | Wald statistic | *P* value | *OR* (95% *CI*) |
|---|---|---|---|---|---|
| Constant | -3.964 | 0.802 | 24.447 | <0.001 | - |
| APACHE II scores | 1.032 | 0.404 | 6.537 | 0.011 | 2.807 (1.272-6.192) |
| Fecal incontinence | 2.011 | 0.694 | 8.401 | 0.004 | 7.470 (1.918-29.097) |
| Stool frequency | 1.005 | 0.439 | 5.240 | 0.022 | 2.733 (1.155-6.462) |
| Stool consistency | 0.995 | 0.438 | 5.156 | 0.023 | 2.703 (1.146-6.379) |
| Herbal enema | 1.430 | 0.485 | 8.694 | 0.003 | 4.180 (1.615-10.818) |

Note: IAD no = 0, APACHE II score <15 = 0, herbal enema no = 0, fecal incontinence no = 0, stool frequency ≤3 per day = 0, nonwatery stool = 0. Abbreviations: APACHE II, acute physiology and chronic health evaluation II; SE, standard error; OR, odds ratio; 95% CI, 95% confidence interval.

*Development and evaluation of the predictive nomogram*

A nomogram was subsequently developed on the basis of the predictors identified above (**Figure 2**). The formula of the model was Ln[P/(1-P)] = -3.964 + 1.032 × APACHE II scores + 2.011 × Fecal incontinence + 1.005 × Stool frequency + 0.995 × Stool consistency + 1.430 × Herbal enema. When this tool is used, individual scores are assigned for each predictor and then summed together to produce a total score that can be used to establish the overall risk of IAD. When this model was used, the C-index for predicting IAD incidence was 0.836. The corrected curve revealed that this model was able to effectively predict IAD incidence (**Figure 3A**). The Hosmer-Lemeshow test also confirmed good model fit ($\chi^2$=3.749, *P*=0.711). ROC curves were subsequently constructed on the basis of the values derived from this predictive model and IAD incidence (**Figure 4A**). The AUC value was 0.836 (95% CI: 0.779-0.894; *P*<0.01), the sensitivity and specificity values were 86.5% and 66.7%, respectively.

Internal validation further supported the robustness of the model. The calibration curve for the internal validation set showed that overall, the model's predictions had a reasonable correspondence with the real-world occurrences of IAD, despite differences between the curves

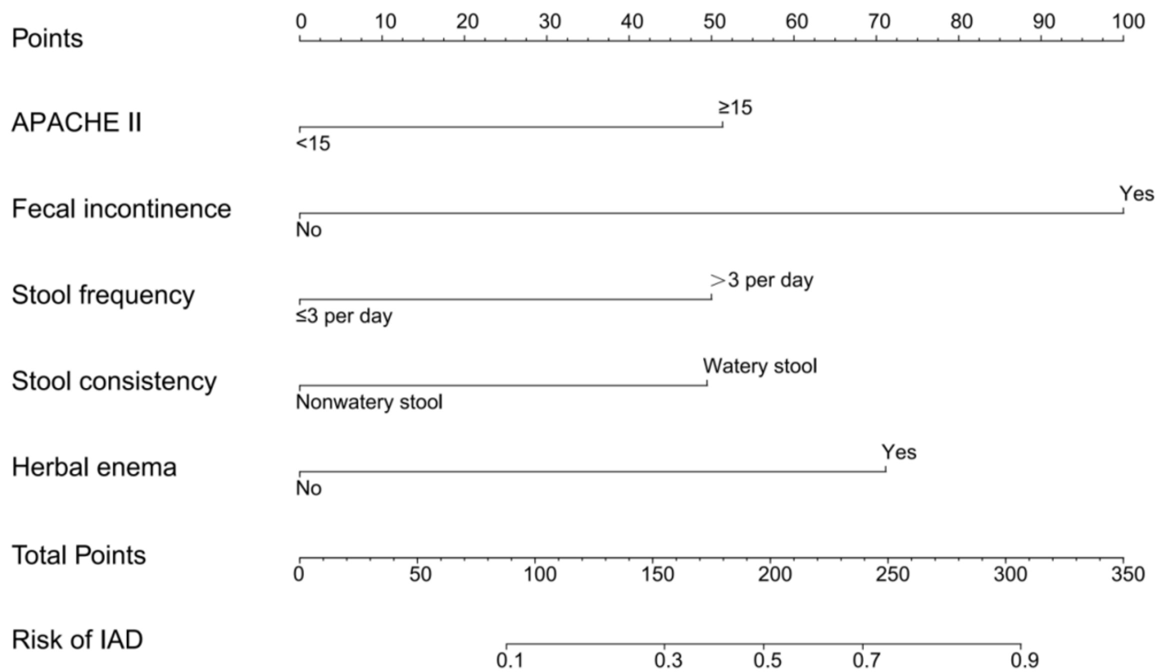


**Figure 2.** Nomogram for the prediction of IAD in SAP patients. Abbreviations: APACHE II, acute physiology and chronic health evaluation II; IAD, incontinence-associated dermatitis.

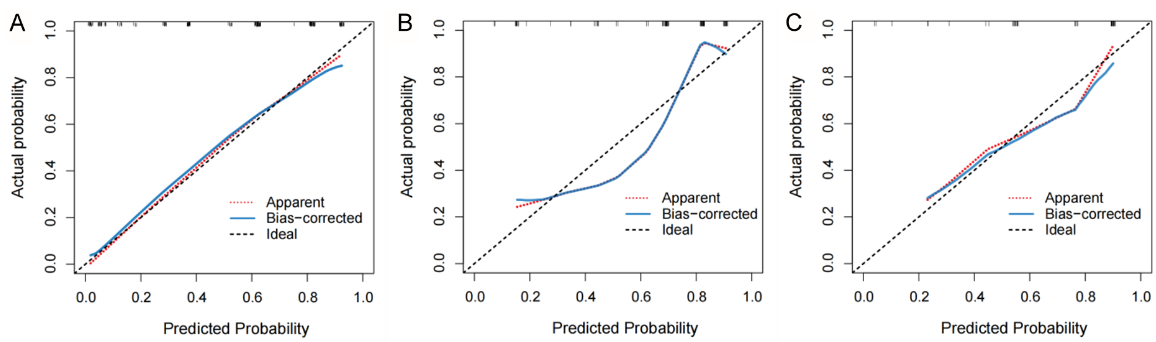


**Figure 3.** Calibration curves for the internal validation of the developed predictive nomogram. A: Training set; B: Testing set; C: External validation set.

(**Figure 3B**). The AUC for the internal validation was 0.825 (95% CI: 0.728-0.921; $P<0.01$), with a sensitivity of 82.0% and specificity of 72.4% (**Figure 4B**). External validation was conducted using an independent dataset to assess generalizability. The calibration curve for the external validation set showed that the predicted probabilities were in substantial agreement with the observed IAD incidence (**Figure 3C**), confirming the model's applicability beyond the training population. The AUC for the external validation was 0.788 (95% CI: 0.644-0.933; $P<0.01$), with a sensitivity of 92.9% and specificity of 57.7% (**Figure 4C**). Although the specificity was slightly lower than in the internal validation, the high sensitivity and acceptable AUC indicate that the model remains effective for identifying individuals at risk of IAD in external settings.

## Discussion

To the best of our knowledge, this is the first investigation of the incidence of IAD in Chinese patients with SAP. The study also developed a predictive nomogram using the identified independent predictors. The results of this study can assist in the early identification of patient

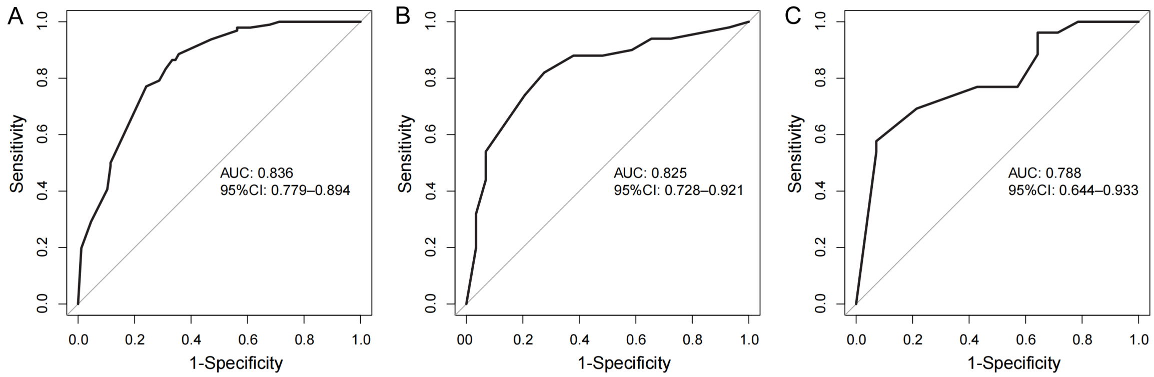


**Figure 4.** ROC curve for the prediction of IAD incidence in SAP patients. A: Training set; B: Testing set; C: External validation set. Abbreviations: AUC, area under curve; 95% CI, 95% confidence interval.

groups at high risk for developing IAD and provide a scientific basis for the early prevention and treatment of IAD by medical staff. The study revealed a high incidence (57%) of IAD in Chinese patients with SAP. The findings revealed that the APACHE II score, fecal incontinence, stool consistency, stool frequency, and herbal enema were independent predictors of IAD in SAP patients.

The present analyses revealed that 57% of Chinese SAP patients experienced IAD in this study, with this rate being higher than that reported in other critically ill patients in studies conducted in other countries [20, 21]. These differences may be attributable to the geographical location of the study subjects, although the rate reported herein was also higher than that reported in other studies from China [22], likely owing to differences in treatment programs associated with the disease. Nonsurgical SAP patients are often treated with traditional Chinese medicine, which is rare in other critically ill patients. Thus, special attention should be given to the prevention of IAD in patients with SAP, especially those treated with traditional Chinese medicine.

The APACHE II score was one of the most important factors for predicting the development of IAD. Specifically, an APACHE II score ≥15 upon admission was associated with a greater risk of IAD than lower scores were, in contrast to one prior report [16]. In that study, the APACHE II score was assessed as a categorical variable, potentially explaining this discrepancy. Patients with APACHE II scores ≥15 face more critical illness, intestinal dysbiosis, and poorer immunity [23] contributing to diarrhea, which increases the moisture content to which the skin is exposed and can cause IAD development. Critically, patients also frequently exhibit low oxygen saturation such that capillary circulation is relatively poor and the skin is hypoxic. This further impairs skin tolerance and compromises the repair of the skin following external injury, increasing the risk of IAD onset following fecal stimulation and related damage [24]. Moreover, higher APACHE II scores have been linked with an increased risk of stress injuries [25], confirming the relationship between this variable and skin damage. Therefore, medical staff may leverage APACHE II scores to identify high-risk patients such that they can intervene at an early time point.

Fecal incontinence, stool frequency, and stool consistency were also found to be independent predictors of IAD development in Chinese patients with SAP, whereas the predictive model did not find a significant association between urinary incontinence and IAD. With respect to incontinence, a prior meta-analysis by Wei et al [26]. involving 10 studies and 40,039 patients reported that urinary incontinence or dual urinary/fecal incontinence was associated with a reduction in IAD risk relative to fecal incontinence alone. Other studies, however, have linked dual incontinence to higher IAD rates than fecal incontinence alone [27]. Fecal incontinence, at the very least, is strongly linked with greater IAD risk than urinary incontinence alone [27, 28]. This may be attributable to the fact that feces contain high levels of lipolytic enzymes and proteases that can cause damage to the stratum corneum of the skin, disrupting barrier integrity and contributing to IAD incidence. The effect of urinary incontinence on IAD was not addressed in the present study, as the included participants were placed on urinary catheters, and there was no way to determine whether they suffered from urinary incontinence.

These results revealed that patients who had more than 3 stools per day were at a higher risk of IAD, which is in line with past reports [19]. This observation is likely associated with the approaches used to treat SAP patients, as 57.9% (175/302) and 74.2% (224/302) of patients in this study were administered oral herbal medicines and herbal enemas, respectively. As such, the number of stools produced by these patients was greater than that produced by patients with many other forms of critical illness. Greater stool frequency and prolonged cutaneous irritation can reduce skin tolerance and increase the risk of damage. IAD rates were higher among those SAP patients treated herein who had watery stools than among those without watery stools, which is consistent with evidence linking watery stools to IAD incidence [16, 29]. Rapid passage of food through the intestines results in inadequate absorption of water and certain solids (including digestive enzymes), resulting in the formation of watery stools, which are more damaging than nonwatery stools because of the higher density of digestive enzymes and the greater area of contact with the skin [29, 30], leading to the development of IAD. This suggests that nurses should keep the patient's skin clean and dry. In addition to the timely changing of nursing pads or sheets, a skin protectant can also be applied to the surface of the skin after cleaning to form a barrier that will improve cutaneous resistance [31, 32].

According to the logistic regression analyses, patients receiving herbal enemas presented a 4.180-fold greater risk of developing IAD than did other SAP patients. Treatment with traditional Chinese medicine can not only shorten the time taken for serum amylase elevation and reduce the incidence of complications associated with SAP [33], but also promote gastrointestinal peristalsis and reduce intra-abdominal hypertension [15]. However, this effect can lead to increased stool frequency, which can continue to irritate the skin. In addition, herbal enemas require that the medicinal solution be retained in the body for a relatively long time and are also usually administered between 1 and 3 times per day (usually 3 or 4 times per day in clinical practice), which can be increased in severely ill patients [15]. The administration of multiple herbal enemas results in watery stools, increasing the area of the skin in contact with the stool and thus leading to an increased risk of IAD. Therefore, for SAP patients receiving traditional Chinese medicine treatment, nurses should increase the frequency of observation and clean the patient's bed promptly [34]. Moreover, nurses should apply fecal collection devices at an early stage in accordance with the patient's condition [35]. This would not only facilitate the effect of the enema but also allow for drainage and assist nurses in the accurate recording of inside and outside.

The predictive model developed in this study showed consistent performance across different datasets. The results from the training set (AUC=0.836) were supported by internal validation (AUC=0.825) and external validation (AUC=0.788), suggesting the model may be applicable to similar patient populations. The model demonstrated sensitivity of 86.5% and specificity of 66.7%, indicating it may be useful for identifying patients at risk of developing IAD. The Hosmer-Lemeshow test ($\chi^2$=3.749, $P$=0.711) and calibration curves indicated reasonable agreement between predicted and observed outcomes. Importantly, the five independent predictors identified herein can be readily extracted from medical records without any need for specialized collection or recording, reducing the time and energy required to identify high-risk patients at an early time point when effective interventions can be implemented. The findings of this study have important implications for the care of patients with SAP. The predictive model can be used by nurses to determine the risk of IAD development in patients with SAP, allowing them to develop a targeted care plan that can reduce the incidence of IAD in SAP patients, increasing the efficacy of traditional Chinese medicine treatment and ultimately improving the health outcomes of patients.

## Limitations

This study has several limitations. First, despite the inclusion of a large number of critically ill patients from southwestern China, the patients were recruited from a single center, which may limit the generalizability of the findings. While external validation was performed using an independent dataset, there was a relatively small sample size of this validation cohort. In the future, expanding the scope of this study through multicenter investigative efforts has the potential to clarify the representativeness and reliability of these data. Second, the study was a retrospective analysis based on electronic medical records, which may also result in limitations. Finally, factors such as poor care and humidity in the ward environment may promote the development of IAD; these factors were not addressed in the present study. In the future, the effects of different care interventions and environments on the development of IAD should be investigated.

## Conclusions

The present study revealed a 57% incidence of IAD in Chinese patients with SAP. Moreover, an APACHE II score ≥15, the use of Chinese medicine enemas, fecal incontinence, a stool frequency >3 per day, and watery stools were predictors of IAD development in Chinese SAP patients. A predictive nomogram was constructed using these factors for the early prediction of IAD development in SAP patients, and internal validation confirmed that the model was effective. In the nomogram, a higher total score reflects a greater risk of IAD development. This approach would allow nurses to identify patients with SAP at high risk of developing IAD simply and quickly, which would be beneficial for the treatment and management of SAP.

## Disclosure of conflict of interest

None.

**Address correspondence to:** Huan Liu, Department of Critical Care Medicine, West China Hospital, Sichuan University/West China School of Nursing, Sichuan University, No. 37, Guoxue Lane, Wuhou District, Chengdu 610041, Sichuan, China. Tel: +86-028-85423369; E-mail: liuhuan881129@163.com

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