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ORIGINAL RESEARCH

Establishing a Predictive Model for Acute Postoperative Pain at PACU Awakening Based on Preoperative Hypoalbuminemia and Anemia: Clinical Implications for Perioperative Nursing

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Background: The management of acute postoperative pain remains a major challenge in perioperative nursing, as it delays recovery and impacts patient satisfaction. Physiological markers such as preoperative serum albumin and hemoglobin are important indicators of pain risk but are often underutilized in conventional nursing assessments.

Methods: This single-center, retrospective cohort study, grounded in the Symptom Management Theory, analyzed data from 790 surgical patients who underwent procedures at the First Affiliated Hospital of Wenzhou Medical University between January and December 2023. Preoperative hypoalbuminemia and anemia were identified through routine laboratory tests. The primary outcome was acute postoperative pain, assessed upon awakening in the Post-Anesthesia Care Unit (PACU). Their associations with this outcome were examined using multivariable logistic regression, adjusting for key confounders including analgesic pump use. Finally, a predictive nomogram was developed to visualize the risk.

Results: The incidence of acute postoperative pain at PACU Awakening was 45.1%. Both preoperative hypoalbuminemia (OR 1.68, 95% CI 1.19–2.39, p = 0.003) and anemia (OR 1.50, 95% CI 1.04–2.16, p = 0.030) were independent predictors of acute postoperative pain at PACU Awakening. The nomogram demonstrated good calibration and acceptable discrimination (AUC = 0.690, 95% CI 0.653–0.726). Decision curve analysis showed a positive net clinical benefit across a wide range of threshold probabilities.

Conclusion: Preoperative hypoalbuminemia and anemia are significant predictors of acute postoperative pain at PACU Awakening. Integrating these biomarkers into routine perioperative nursing assessments enables early identification of at-risk patients and facilitates evidence-based interventions such as nutritional optimization and anemia correction, fostering proactive and personalized pain management strategies. Decision curve analysis showed a positive net clinical benefit across a wide range of threshold probabilities.

Keywords: acute postoperative pain, PACU, hypoalbuminemia, anemia, pain management, perioperative nursing

Introduction

Behind the staggering global annual figure of over 310 million surgeries[1] lies a pressing clinical reality: acute postoperative pain remains highly prevalent and distressing for patients.[2,3] This pain, typically lasting 3–7 days, acts as a critical barrier to recovery when poorly managed, leading to delayed mobilization, impaired physical function, prolonged hospitalization, and increased healthcare costs.[4] In particular, the immediate pain experienced by patients when waking up in the post-anesthesia care unit (PACU) is not only the beginning of postoperative stress responses but also a key predictor of later recovery quality. However, poorly managed acute pain can easily develop into chronic pain, further complicating the rehabilitation process.[5]

Serum albumin and hemoglobin are routinely monitored preoperative indicators that provide valuable insights into a patient's nutritional and hematologic status. Hypoalbuminemia, defined as a serum albumin level < 35 g/L, reflects poor

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nutritional reserve and is associated with delayed wound healing, immune dysfunction, longer hospitalization, and increased mortality.[6–11] Similarly, preoperative anemia, defined by WHO criteria (Hb < 130 g/L in men, < 120 g/L in women), affects approximately one-third of surgical patients and is a well-established risk factor for increased transfusion rates and postoperative complications.[12–16] These biomarkers are routinely assessed by perioperative nurses, positioning them as useful tools for identifying patients at higher risk for adverse surgical outcomes.

Despite substantial research links these biomarkers to broader surgical outcomes, their specific association with acute pain at PACU awakening remains inadequately explored. We selected preoperative albumin (ALB) and hemoglobin (Hb) as core predictors based on the Symptom Management Theory (SMT).[17,18] SMT posits that symptoms like pain are multidimensional experiences driven by modifiable biological antecedents, and that early identification of these factors is crucial for proactive symptom control. Biologically, ALB serves as a negative acute-phase protein reflecting systemic inflammation, which can modulate neural sensitivity and impair tissue repair. Meanwhile, Hb levels determine tissue oxygen-carrying capacity; preoperative anemia triggers localized hypoxia and the release of algogenic substances (eg, lactate and pro-inflammatory cytokines), thereby lowering the pain threshold. Crucially, unlike non-modifiable factors such as age or surgical type, ALB and Hb are clinically actionable. Identifying these risks enables perioperative nurses to implement proactive interventions-such as nutritional optimization and anemia correction—shifting care from reactive management to predictive prevention.

Grounded in the SMT, which conceptualizes biological status as a critical antecedent to symptom experience, this study aims to bridge this gap. The objectives are twofold: first, to investigate the independent associations between preoperative hypoalbuminemia, anemia, and acute pain at PACU awakening; and second, to develop and validate a practical predictive nomogram. This model is designed to empower perioperative nurses by enabling early risk stratification, facilitating timely nutritional support, and optimizing individualized pain management strategies.

Materials and Methods

Ethics Approval

This study was conducted in accordance with the ethical standards of the institutional and national research committees and with the 1964 Declaration of Helsinki and its later amendments. Ethical approval was obtained from the Research Ethics Committee of the First Affiliated Hospital of Wenzhou Medical University (Approval No. KY2024-019). As a retrospective cohort study, this research did not involve clinical trials; therefore, a clinical trial registration number was not applicable. Due to the use of anonymized patient data and the retrospective nature of the study, a waiver of informed consent was granted by the ethics committee.

Participants and Randomization

This study was designed as a single-center, retrospective cohort study. From an initial population of 100,858 adult patients who underwent postoperative observation in the PACU between January 1, 2023, and December 31, 2023. Data were retrieved from the hospital's electronic medical record system and anesthesia information management system, encompassing all adult patients who underwent postoperative observation during the study period.

Eligible participants met the following inclusion criteria: (1) postoperative observation after surgery, (2) age≥18 years, (3) ability to effectively communicate and provide reliable pain assessments, and (4) completion of preoperative clinical evaluations, including routine laboratory testing and medical history documentation. Patients were excluded if they had: (1) incomplete medical or anesthesia records, (2) diagnosed cognitive impairment or mental illness (eg, dementia, depression, schizophrenia), (3) a history of chronic pain lasting more than three months, or (4) ongoing psychiatric or pain management treatment.

To construct the analytical cohort, we employed a stratified random sampling strategy and completed the final cohort construction using R software (version 4.4.0). To ensure that the sample accurately reflected the diversity of surgical practice and the temporal distribution throughout the year, we defined strata based on the primary surgeon and surgery date. The specific reason for choosing this sampling method was its convenience for high-fidelity manual data verification-ensuring precise matching of preoperative biomarkers, surgical invasiveness, and individualized PCIA

configurations, which would be difficult to achieve in a population sample of over 100,000 individuals. The final sample size of 790 patients provided sufficient statistical power for multivariable modeling, strictly meeting the standard requirement of at least 10 events per variable (EPV).

Data Collection

Data were retrospectively collected from three institutional information systems: the hospital's electronic medical record system, the anesthesia information management system, and the laboratory information system. Relevant variables, including demographic information, preoperative, intraoperative, and postoperative data, were extracted. This included patient age, sex, BMI, educational level, comorbidities, surgical site, anesthesia type, surgery duration, anesthesia duration, intraoperative medication use, and postoperative pain assessment records.

Preoperative serum albumin and hemoglobin levels were obtained from routine laboratory tests performed 1–3 days before surgery. Hypoalbuminemia was defined as a serum albumin concentration < 35 g/L, and anemia was defined as a hemoglobin level < 120 g/L for men and < 110 g/L for women. Postoperative pain was assessed using the Visual Analog Scale (VAS) when the patient first achieved a Modified Aldrete Score of ≥ 9 (or when fully oriented to person, place, and time). The primary outcome was the VAS score at rest at this time point. To reflect the overall incidence of postoperative pain and support proactive nursing management, the outcome was dichotomized as "no pain" (VAS = 0) and "pain" (VAS > 0). This threshold ensures that patients experiencing even mild discomfort are identified for early nursing assessment and timely intervention, thereby preventing the escalation to severe pain. The VAS is a 10 - centimeter line anchored at 0 ("no pain") and 10 ("worst imaginable pain"), where the patient indicated their pain intensity.

Postoperative analgesic management followed a standardized clinical protocol. For patients receiving Patient-Controlled Intravenous Analgesia (PCIA), the pump was configured with Sufentanil, and the dosage was strictly titrated according to the patient's body weight to ensure pharmacological consistency. The presence or absence of a PCIA pump was then included in the multivariable model as a covariate to adjust for its potential influence on pain outcomes.

To ensure data integrity, two trained research nurses independently performed data extraction and cross-verification. Any discrepancies were resolved through discussion with a senior researcher. Data were entered into a secure Microsoft Access database with double-entry verification. The anonymized dataset was accessible exclusively to authorized research personnel, ensuring the accuracy, consistency, and completeness of all variables included in the analysis.

Statistical Analysis

Statistical analyses were performed using R software (version 4.4.0; R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were summarized as mean ± standard deviation (SD) or median with interquartile range (IQR), based on the distribution assessed by the Kolmogorov–Smirnov test. Categorical variables were presented as counts and percentages. Group comparisons were conducted using the *t* test or Mann–Whitney *U*-test for continuous variables and the chi-square test for categorical variables.

Univariate logistic regression was used to identify potential factors associated with acute postoperative pain. Variables with a p-value < 0.05 were entered into a multivariable logistic regression model to identify independent predictors of acute postoperative pain. Model discrimination and calibration were evaluated using the receiver operating characteristic (ROC) curve, area under the curve (AUC), and calibration plots based on 1000 bootstrap resamples. Decision curve analysis (DCA) was applied to assess the model's clinical benefit. Statistical significance was set at $p < 0.05$.

Results

Basic Characteristics of the Participants

A total of 790 postoperative patients were analyzed (Table 1). Of these, 356 patients (45.1%) experienced acute postoperative pain at PACU Awakening, while 434 patients (54.9%) did not report pain. The cohort had a mean age of 56.1 ± 16.4 years and a mean BMI of 23.4 ± 3.5 kg/m^2, with a nearly equal gender distribution (47.9% male, 52.1% female). More than half of the participants (55.6%) had completed only primary school or less. Common comorbidities

Table 1 Overall Patients Baseline (N = 790)

Variable	Number of Cases (%)
Sex	
Male	378 (47.85%)
Female	412 (52.15%)
Educational Level	
Elementary school and below	439 (55.57%)
Junior high school	202 (25.57%)
High school and above	149 (18.86%)
Profession	
Agricultural workers	557 (70.51%)
Public officials	192 (24.30%)
Cadres and staff	41 (5.19%)
Type Of Health Insurance	
NCMS Insurance	422 (53.42%)
Cadre insurance	368 (46.58%)
Sleep Condition	
Normal	633 (80.13%)
Suboptimal	104 (13.16%)
Poor	53 (6.71%)
History Of Sedative And Analgesic Use	
No	731 (92.53%)
Yes	59 (7.47%)
History Of Previous Surgery	
No	400 (50.63%)
Yes	390 (49.37%)
Hypertension	
No	561 (71.01%)
Yes	229 (28.99%)
Diabetes	
No	703 (88.99%)
Yes	87 (11.01%)
Stroke	
No	770 (97.47%)
Yes	20 (2.53%)
Coronary Heart Disease	
No	774 (97.97%)
Yes	16 (2.03%)
Smoking	
No	605 (76.58%)
Yes	185 (23.42%)
Drinking	
No	573 (72.53%)
Yes	217 (27.47%)
Preoperative Low Albumin	
No	494 (62.53%)
Yes	296 (37.47%)
Preoperative Low Hemoglobin	
No	580 (73.42%)
Yes	210 (26.58%)
Surgical Site	
Body Surface Tissue	163 (20.63%)
Head and Face	52 (6.58%)

(*Continued*)

Table 1 (Continued).

Variable	Number of Cases (%)
Chest	59 (7.47%)
Abdomen	304 (38.48%)
Urinary	97 (12.28%)
Orthopedics	115 (14.56%)
Type of Anesthesia	
General Anesthesia	643 (81.39%)
Combined	37 (4.68%)
Intrathecal	74 (9.37%)
Others	36 (4.56%)
Use of Inhalation Anesthetics	
No	135 (17.09%)
Yes	655 (82.91%)
Analgesic Pump	
No	655 (82.91%)
Yes	135 (17.09%)
Intraoperative Bleeding	
Below 200mL	766 (96.96%)
Above 200mL	24 (3.04%)
Drainage Tube	
No	338 (42.78%)
Yes	452 (57.22%)
Acute Postoperative Pain Score (VAS)	
0	434 (54.94%)
1	201 (25.44%)
2	37 (4.68%)
3	31 (3.92%)
4	31 (3.92%)
5	55 (6.96%)
6	1 (0.13%)
Acute Postoperative Pain	
No	434 (54.94%)
Yes	356 (45.06%)

Notes: Values are presented as n (%); Percentages are based on the total number of patients (N = 790).
Abbreviations: VAS, Visual Analogue Scale; NCMS, New Cooperative Medical Scheme.

included hypertension (29.0%), diabetes mellitus (11.0%), stroke (2.5%), and coronary heart disease (2.0%). Preoperative hypoalbuminemia was present in 296 patients (37.5%), and 210 patients (26.6%) had preoperative anemia. Pain severity assessment revealed that 703 patients (89.0%) reported mild to moderate pain, while 87 patients (11.0%) experienced moderate to severe pain. The descriptive statistics for continuous variables, including age, BMI, and surgery duration, are provided in Table 2.

In univariate comparisons between patients with and without postoperative pain (Table 3), several factors demonstrated statistically significant differences, including sex ($p = 0.001$), age ($p < 0.001$), preoperative hypoalbuminemia ($p < 0.001$), preoperative anemia ($p < 0.001$), type of anesthesia ($p = 0.016$), surgery duration ($p < 0.001$), anesthesia duration ($p < 0.001$), intraoperative analgesic pump use ($p < 0.001$), and drainage tube placement ($p < 0.001$).

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Table 2 Descriptive Statistics General Population Characteristics (N = 790)

Variable	Min	P25	P50	Mean ± SD	P75	Max
Age	18	44	56	56.14 ± 16.44	69	95
Height	141	158	162.5	162.70 ± 7.53	168	186
Weight	37	55	60	62.10 ± 11.03	69	123
BMI	14.34	21.05	23.33	23.41 ± 3.48	25.46	42.56
Duration of anesthesia	8.00	67.25	108.00	127.81± 79.43	168.00	552.00
Duration of surgery	6	44	81	98.70 ± 71.97	137	464

Notes: Values are expressed as minimum, 25th percentile (P25), 50th percentile (median, P50), mean ± standard deviation (SD), 75th percentile (P75), and maximum; Anaesthesia and surgery durations are expressed in minutes.
Abbreviations: BMI, body mass index.

Table 3 Analysis of People with Acute Postoperative Pain in Different States (N = 790)

Variable	Non-Acute Postoperative Pain (N = 434)	Acute Postoperative Pain (N = 356)	*P*-value
Sex			0.001*
Male	232 (53.46%)	146 (41.01%)	
Female	202 (46.54%)	210 (58.99%)	
Age	53.56 ± 16.04	59.29 ± 16.39	<0.001*
Height	162.79 ± 7.67	162.72 ± 7.40	0.897
Weight	62.31 ± 10.93	61.85 ± 11.16	0.562
BMI	23.47 ± 3.36	23.33 ± 3.62	0.559
Educational level			0.123
Elementary school and below	228 (52.53%)	211 (59.27%)	
Junior high school	115 (26.50%)	87 (24.44%)	
High school and above	91 (20.97%)	58 (16.29%)	
Profession			0.291
Agricultural workers	296 (68.20%)	261 (73.31%)	
Public officials	114 (26.27%)	78 (21.91%)	
Cadres and staff	24 (5.53%)	17 (4.78%)	
Type Of Health Insurance			0.139
NCMS Insurance	221 (50.92%)	201 (56.46%)	
Cadre insurance	213 (49.08%)	155 (43.54%)	
Sleep Condition			0.212
Normal	354 (81.57%)	279 (78.37%)	
Suboptimal	57 (13.13%)	47 (13.20%)	
Poor	23 (5.30%)	30 (8.43%)	
History Of Sedative And Analgesic Use			0.804
No	403 (92.86%)	328 (92.13%)	
Yes	31 (7.14%)	28 (7.87%)	
History Of Previous Surgery			0.544
No	215 (49.54%)	185 (51.97%)	
Yes	219 (50.46%)	171 (48.03%)	
Hypertension			0.250
No	316 (72.81%)	245 (68.82%)	
Yes	118 (27.19%)	111 (31.18%)	
Diabetes			0.327
No	391 (90.09%)	312 (87.64%)	
Yes	43 (9.91%)	44 (12.36%)	
Stroke			1.000
No	423 (97.47%)	347 (97.47%)	
Yes	11 (2.53%)	9 (2.53%)	

(*Continued*)

Table 3 (Continued).

Variable	Non-Acute Postoperative Pain (N = 434)	Acute Postoperative Pain (N = 356)	*P*-value
Coronary Heart Disease			0.095
No	429 (98.85%)	345 (96.91%)	
Yes	5 (1.15%)	11 (3.09%)	
Smoking			0.228
No	340 (78.34%)	265 (74.44%)	
Yes	94 (21.66%)	91 (25.56%)	
Drinking			0.217
No	323 (74.42%)	250 (70.22%)	
Yes	111 (25.58%)	106 (29.78%)	
Preoperative Low Albumin			<0.001*
No	311 (71.66%)	183 (51.40%)	
Yes	123 (28.34%)	173 (48.60%)	
Preoperative Low Hemoglobin			<0.001*
No	344 (79.26%)	236 (66.29%)	
Yes	90 (20.74%)	120 (33.71%)	
Surgical Site			0.114
Body Surface Tissue	99 (22.81%)	64 (17.98%)	
Head and Face	33 (7.60%)	19 (5.34%)	
Chest	32 (7.37%)	27 (7.58%)	
Abdomen	151 (34.79%)	153 (42.98%)	
Urinary	59 (13.59%)	38 (10.67%)	
Orthopedics	60 (13.82%)	55 (15.45%)	
Duration of surgery	84.37 ± 61.49	116.17 ± 79.64	<0.001*
Type of Anesthesia			0.016*
General Anesthesia	345 (79.49%)	298 (83.71%)	
Combined	15 (3.46%)	22 (6.18%)	
Intrathecal	50 (11.52%)	24 (6.74%)	
Others	24 (5.53%)	12 (3.37%)	
Duration of anesthesia	111.77 ± 68.38	147.49 ± 87.27	<0.001*
Use Of Inhalation Anesthetics			0.410
No	79 (18.20%)	56 (15.73%)	
Yes	355 (81.80%)	300 (84.27%)	
Analgesic Pump			<0.001*
No	388 (89.40%)	267 (75.00%)	
Yes	46 (10.60%)	89 (25.00%)	
Intraoperative Bleeding			0.263
Below 200mL	424 (97.70%)	342 (96.07%)	
Above 200mL	10 (2.30%)	14 (3.93%)	
Drainage Tube			<0.001*
No	212 (48.85%)	126 (35.39%)	
Yes	222 (51.15%)	230 (64.61%)	

Notes: Continuous variables are expressed as mean ± SD and compared using the independent-sample t-test; categorical variables are presented as n (%) and compared using the chi-square or Fisher's exact test, as appropriate. * $p < 0.05$.
Abbreviations: BMI, body mass index; NCMS, New Cooperative Medical Scheme.

Risk Factors and Multivariable Logistic Regression Analysis

After adjusting for potential confounders in the multivariable logistic regression, preoperative hypoalbuminemia and anemia remained independently associated with PACU Awakening pain (Table 4). As shown in the predictive model (Figure 1), after comprehensively controlling for surgical site, duration, and standardized PCIA use, both biomarkers were identified as significant independent predictors. Specifically, the odds of experiencing early PACU resting pain were

1.50 times higher in patients with preoperative anemia (adjusted OR 1.50, 95% CI 1.04–2.16, p = 0.030) and 1.68 times higher in those with hypoalbuminemia (adjusted OR 1.68, 95% CI 1.19–2.39, p = 0.003). Other independent risk factors identified in the adjusted model included female sex and longer surgical duration.

These findings suggest that preoperative nutritional and hematologic deficiencies, which are routinely assessed in clinical practice, may serve as valuable indicators for early identification of patients at risk for postoperative pain, even after accounting for the underlying surgical insult. This highlights the importance of integrating these readily available biomarkers into perioperative risk assessment protocols.

Model Validation and Clinical Application

To make the predictive model more accessible and practical at the bedside, we developed a nomogram (Figure 2) that visually estimates the probability of acute postoperative pain at PACU Awakening. The nomogram incorporates preoperative albumin and hemoglobin levels, sex, surgery duration, and anesthesia duration — parameters easily measured through routine nursing assessments. By summing the individual scores for each variable, nurses can quickly obtain a total score that corresponds to the patient's predicted risk, facilitating rapid risk stratification at the bedside.

The model's performance was evaluated in terms of three key dimensions: discrimination, calibration, and clinical utility. The area under the receiver operating characteristic (ROC) curve was 0.690 (95% CI: 0.653–0.726, Figure 3), indicating moderate discriminative ability. A calibration plot, generated from 1000 bootstrap resamples, demonstrated good agreement between predicted and observed outcomes (Figure 4), The mean absolute error (MAE) was 0.029 (n=790), indicating minimal overfitting and high reliability. Additionally, decision curve analysis (Figure 5) confirmed that the model provides a positive net clinical benefit across a wide range of clinically relevant threshold probabilities (0.10 to 0.85). Within this window, the model outperformed both the "treat-all" and "treat-none" strategies, highlighting its practical value in clinical decision-making.

Discussion

This study identified preoperative hypoalbuminemia and anemia as independent predictors of acute postoperative pain at PACU Awakening in surgical patients. After adjusting for confounding factors, hypoalbuminemia increased the likelihood of postoperative pain by 68%, while anemia raised the risk by 50%. Female sex, longer anesthesia duration, and longer surgery duration were also associated with a higher incidence of pain. The predictive model showed good calibration and moderate discrimination (AUC = 0.690), suggesting its utility in early risk stratification for perioperative care.

Interpreted through the Symptom Management Theory (SMT), these findings provide a valuable connection between empirical evidence and a theoretical nursing framework. SMT views symptoms, such as postoperative pain, as dynamic experiences that can be managed through an iterative process of assessment, intervention, and evaluation.[17,18] Within this framework, serum albumin and hemoglobin levels serve as objective biomarkers that reflect physiological reserves and a patient's vulnerability to symptoms like pain. Preoperative assessment of these biomarkers allows nurses to identify high-risk patients early, enabling proactive interventions such as nutritional optimization and anemia correction before surgery. Postoperative pain monitoring, as part of the SMT cycle, serves as the evaluation component, ensuring that pain management strategies are tailored and adjusted to the individual patient's needs.

These findings extend existing literature by demonstrating that preoperative nutritional and hematologic deficits are not only predictive of complications and mortality but also of subjective symptoms, specifically acute postoperative pain. Previous studies have linked hypoalbuminemia to systemic inflammation and oxidative stress, both of which sensitize nociceptors and amplify pain responses. Specifically, hypoalbuminemia can lead to an imbalance in cytokine production, resulting in an exaggerated inflammatory response that increases pain sensitivity.[10,19,20] Liu et al[21] reported that hypoalbuminemia predicted early postoperative complications in revision shoulder arthroplasty, reinforcing its prognostic relevance beyond merely indicating malnutrition. Similarly, anemia has been consistently associated with delayed wound healing and increased morbidity.[12,22,23] The underlying mechanisms include impaired oxygen delivery and tissue hypoxia, which activate inflammatory mediators such as prostaglandins and bradykinin, sensitizing peripheral pain

Table 4 Analysis of Univariate Logistic Regression (N = 790)

Variable	OR (95% CI)	*P*-value
Sex		
Male	Reference	
Female	1.65 (1.24, 2.19)	0.001*
Age	1.02 (1.01, 1.03)	<0.001*
Height	1.00 (0.98, 1.02)	0.958
Weight	1.00 (0.98, 1.01)	0.560
BMI	0.99 (0.95, 1.03)	0.555
Educational level		
Elementary school and below	Reference	
Junior high school	0.82 (0.58, 1.14)	0.240
High school and above	0.69 (0.47, 1.01)	0.053
Profession		
Agricultural workers	Reference	
Public officials	0.78 (0.56, 1.08)	0.135
Cadres and staff	0.81 (0.42, 1.53)	0.511
Type Of Health Insurance		
NCMS Insurance	Reference	
Cadre insurance	0.80 (0.60, 1.06)	0.121
Sleep Condition		
Normal	Reference	
Suboptimal	1.05 (0.69, 1.59)	0.831
Poor	1.65 (0.94, 2.94)	0.082
History Of Sedative And Analgesic Use		
No	Reference	
Yes	1.11 (0.65, 1.89)	0.701
History Of Previous Surgery		
No	Reference	
Yes	0.91 (0.69, 1.20)	0.498
Hypertension		
No	Reference	
Yes	1.21 (0.89, 1.65)	0.220
Diabetes		
No	Reference	
Yes	1.28 (0.82, 2.01)	0.277
Stroke		
No	Reference	
Yes	1.00 (0.39, 2.47)	0.999
Coronary Heart Disease		
No	Reference	
Yes	2.69 (0.95, 8.80)	0.062
Smoking		
No	Reference	
Yes	1.24 (0.89, 1.73)	0.199
Drinking		
No	Reference	
Yes	1.23 (0.90, 1.69)	0.190
Preoperative Low Albumin		
No	Reference	
Yes	2.39 (1.78, 3.21)	<0.001*

(*Continued*)

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Table 4 (Continued).

Variable	OR (95% CI)	*P*-value
Preoperative Low Hemoglobin		
No	Reference	
Yes	1.94 (1.41, 2.68)	<0.001*
Surgical Site		
Body Surface Tissue	Reference	
Head and Face	0.89 (0.46, 1.70)	0.733
Chest	1.30 (0.71, 2.39)	0.390
Abdomen	1.56 (1.06, 2.31)	0.023*
Urinary	1.00 (0.59, 1.67)	0.991
Orthopedics	1.42 (0.87, 2.30)	0.159
Duration of surgery	1.01 (1.00, 1.01)	<0.001*
Type of Anesthesia		
General Anesthesia	Reference	
Combined	1.72 (0.86, 3.63)	0.130
Intrathecal	2.87 (1.11, 7.73)	0.029*
Others	0.98 (0.42, 2.34)	0.957
Duration of anesthesia	1.01 (1.00, 1.01)	<0.001*
Use Of Inhalation Anesthetics		
No	Reference	
Yes	1.19 (0.82, 1.74)	0.370
Analgesic Pump		
No	Reference	
Yes	2.80 (1.91, 4.17)	<0.001*
Intraoperative Bleeding		
Below 200mL	Reference	
Above 200mL	1.73 (0.76, 4.09)	0.194
Drainage Tube		
No	Reference	
Yes	1.74 (1.31, 2.33)	<0.001*

Note: Variables with p < 0.05 were entered into the multivariable logistic regression model. * *p < 0.05*.
Abbreviations: OR, odds ratio; CI, confidence interval; BMI, body mass index; NCMS, New Cooperative Medical Scheme.

receptors and lowering pain thresholds.[15,24,25] Together, these biological pathways help explain how hypoalbuminemia and anemia may potentiate acute postoperative pain responses.

Additional findings, including the influence of female sex, surgery duration, and anesthesia time, align with prior research. Women are generally reported to experience greater pain sensitivity due to hormonal fluctuations, variations in endogenous opioid systems, and gender differences in immune responses.[26,27] Furthermore, prolonged surgical and anesthesia durations are linked to increased tissue trauma, a higher inflammatory burden, and longer exposure to anesthetic agents, all of which contribute to greater postoperative pain.[28,29] These findings highlight that postoperative pain is multifactorial, arising from the interaction of biological, procedural, and demographic factors, emphasizing the need for comprehensive, individualized pain management strategies.

From a nursing perspective, this study offers both theoretical and practical insights into perioperative pain management. Grounded in SMT, the proposed model integrates the full cycle of assessment, intervention, and evaluation into perioperative nursing practice. Preoperative evaluation of albumin and hemoglobin allows for objective pain risk assessment. High-risk patients can receive preoperative interventions such as nutritional counseling, anemia correction, and perioperative education. Postoperatively, standardized pain assessments using validated tools allow for timely adjustment of analgesic strategies. When incorporated into electronic nursing documentation systems, this model could

Variable		N	Odds ratio	*P*-value
Preoperative Low Albumin	No	494	Reference	
	Yes	296	1.68 (1.19, 2.39)	0.003
Preoperative Low Hemoglobin	No	580	Reference	
	Yes	210	1.50 (1.04, 2.16)	0.030
Sex	Male	376	Reference	
	Female	414	1.40 (1.01, 1.92)	0.041
Age		790	1.00 (0.99, 1.01)	0.887
Duration of Surgery		790	1.00 (0.99, 1.01)	0.685
Type of Anesthesia	Others	36	Reference	
	Intrathecal	74	0.93 (0.39, 2.25)	0.864
	Combined	37	1.33 (0.48, 3.84)	0.591
	General Anesthesia	643	1.53 (0.73, 3.35)	0.270
Duration of Anesthesia		790	1.00 (0.99, 1.01)	0.780
Analgesic Pump	No	655	Reference	
	Yes	135	1.30 (0.81, 2.10)	0.274
Drainage Tube	No	338	Reference	
	Yes	452	1.04 (0.73, 1.46)	0.837

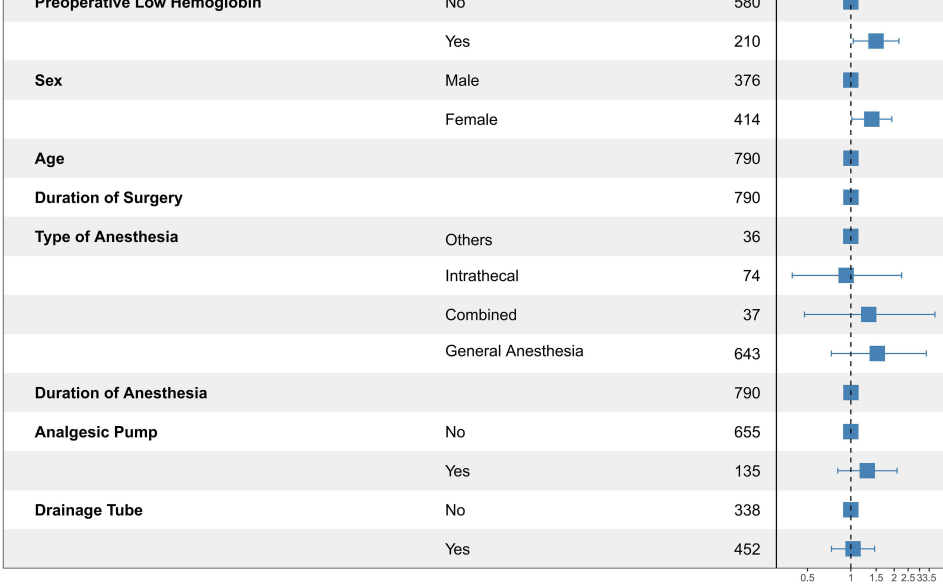

Figure 1 Multifactor logistic regression model of acute postoperative pain at PACU Awakening.

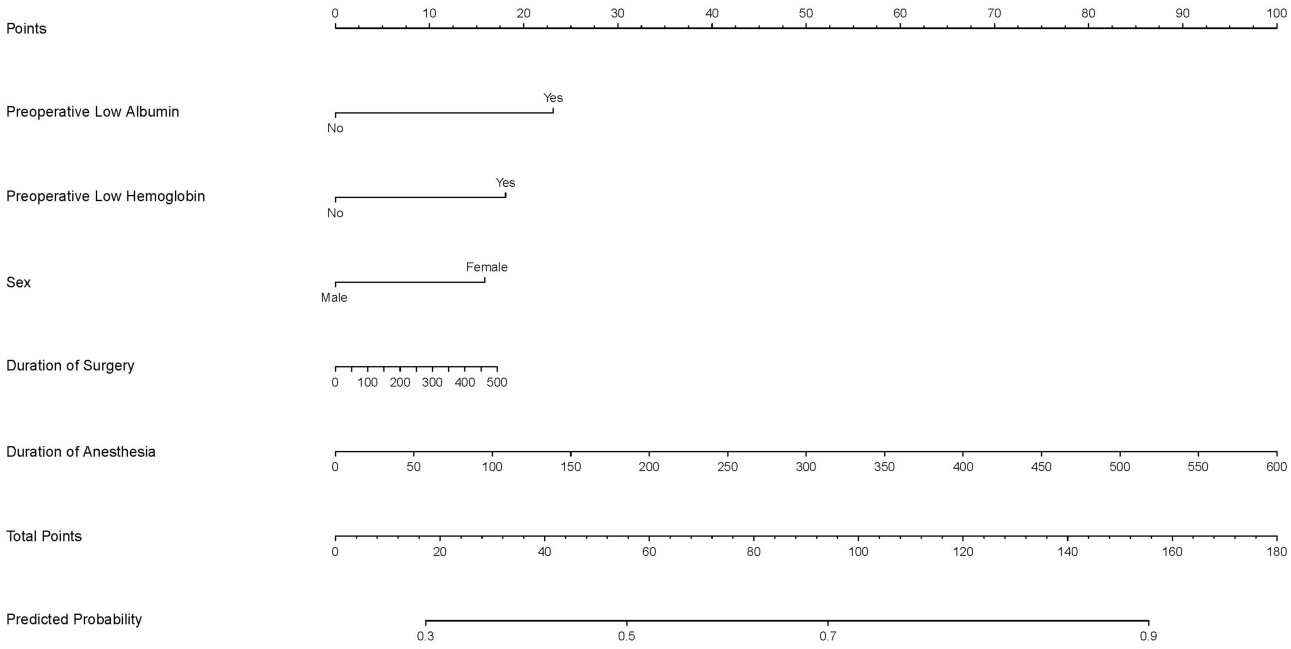

Figure 2 The nomogram model to predict acute postoperative pain at PACU Awakening.

serve as a clinical decision-support tool, generating automated alerts for high-risk patients and enhancing interdisciplinary collaboration between nurses, anesthesiologists, and dietitians. This approach exemplifies precision nursing, utilizing individualized, data-driven interventions to improve outcomes and enhance patient satisfaction.

Several limitations must be acknowledged. First, this study's retrospective, single-center design limits the generalizability of its findings. Although stratified sampling was used to minimize selection bias, variations in surgical practice

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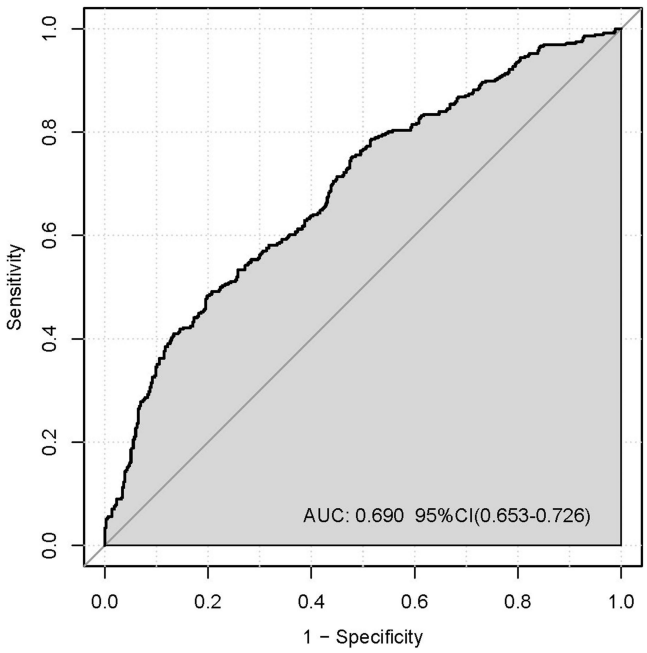

Figure 3 The AUC of the nomogram model.

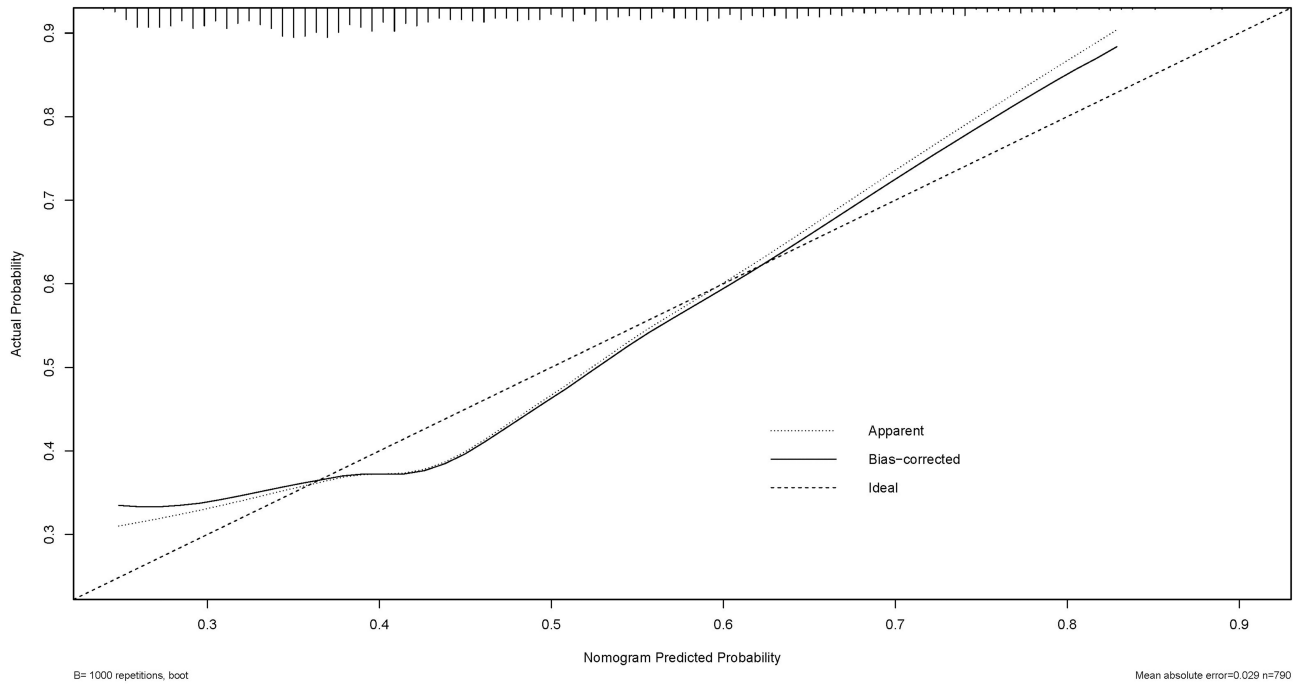

Figure 4 The calibration curve of the nomogram model.

across institutions may affect the external validity of the model. Future prospective, multicenter studies should validate the predictive performance of this model and assess the impact of implementing model-guided interventions in diverse settings. Second, psychosocial variables such as anxiety, coping styles, and pain catastrophizing were not included in this analysis, even though they are known to influence pain perception. Incorporating these variables into future studies could enhance the model's accuracy and predictive power. Lastly, this study focused solely on acute postoperative pain at PACU Awakening; Future research should employ prospective, multicenter designs to validate these findings and utilize

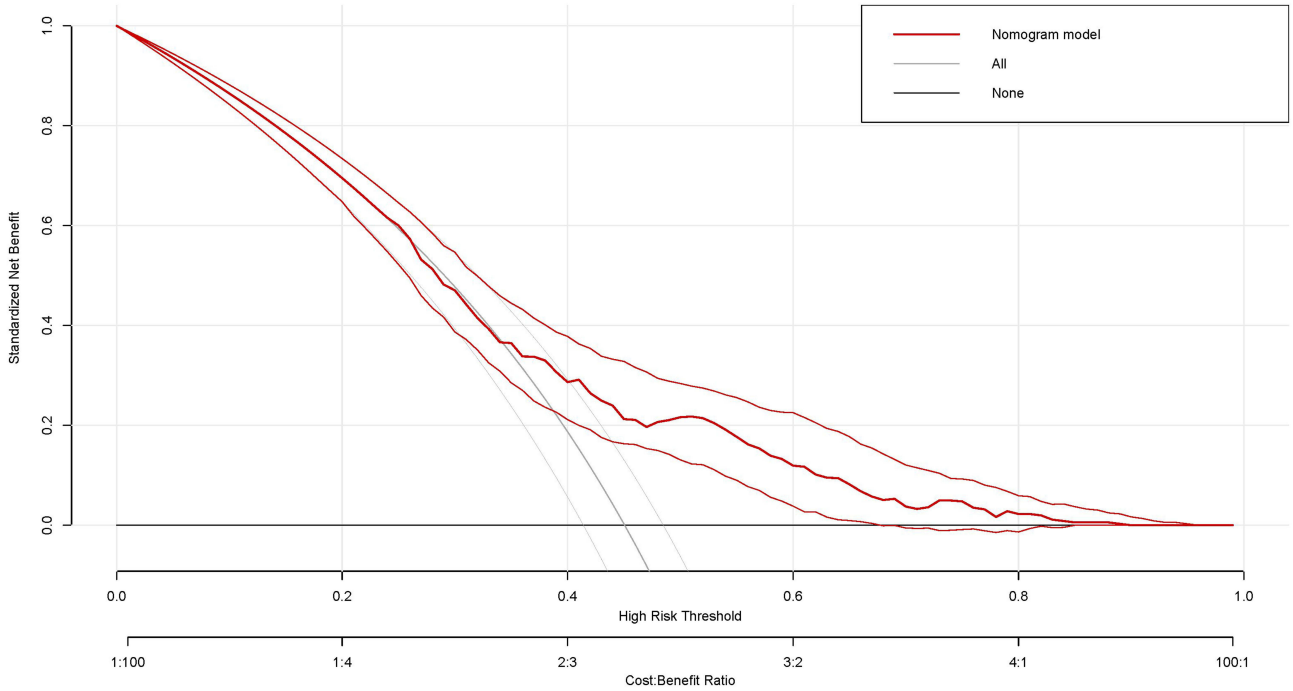

Figure 5 The decision curve of the nomogram model.

longitudinal trajectory analysis to determine whether preoperative nutritional markers can predict the evolution of pain from the acute phase to chronic postsurgical recovery.

Conclusions

In conclusion, preoperative hypoalbuminemia and anemia are significant, modifiable predictors of acute postoperative pain at PACU Awakening. Incorporating these biomarkers into routine preoperative nursing assessments facilitates early risk identification and supports evidence-based interventions, including nutritional optimization and anemia correction. Grounded in the Symptom Management Theory, this predictive model shifts perioperative care from reactive pain management to predictive and preventive nursing. While the model offers moderate predictive value, it provides a pragmatic, evidence-based tool for clinical decision-making. Future research involving longitudinal trajectory analysis and external validation is warranted to further confirm the clinical utility of these predictors in enhancing long-term postoperative recovery.

Data Sharing Statement

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

Ethics Approval and Consent to Participate

This study was approved by the Research Ethics Committee of the First Affiliated Hospital of Wenzhou Medical University (Approval No. KY2024-019). All procedures were performed in accordance with the ethical standards of the institutional research committee and the 1964 Declaration of Helsinki and its later amendments. Because this was a retrospective analysis of anonymized clinical data, the requirement for informed consent was waived by the ethics committee.

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Disclosure

The authors declare that they have no competing interests in this work.

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