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Albumin and neutrophil-to-lymphocyte ratio-based predictive nomogram for post-operative complications following colon cancer resection

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Abstract

Introduction: The albumin combined with the neutrophil-to-lymphocyte ratio (NLR) score may be a useful marker of inflammation, but its associations with post-operative complications in colon cancer patients are unknown.
Objective: This study aims to construct and validate a predictive model incorporating albumin and NLR to predict post-operative complications in patients who underwent colon cancer resection.
Methods: A retrospective analysis was conducted on patients who underwent colon cancer resections between 2019 and 2021 at Sun Yat-sen Memorial Hospital. Clinical characteristics and systemic inflammatory markers, including lymphocytes and neutrophils, were collected. Post-operative complications served as the primary outcome. Logistic regression analyses were performed to identify the potential risk factors for post-operative complications after colon cancer resection. Nomograms with or without albumin and NLR score for post-operative complications were further constructed according to the results of the multivariable logistic regression analysis using the Akaike information criterion.
Results: Pre-operative albumin combined with NLR score (p=0.01; odds ratio [OR]: 2.69; 95% confidence interval [CI]: 1.90–8.06), age (p=0.007; OR: 1.05; 95% CI: 1.01–1.09), intraoperative blood transfusion (p=0.002; OR:5.32; 95% CI: 1.87–15.15), and duration of surgery (p=0.001; OR:1.70; 95% CI: 1.24–2.34) were identified as independent risk factors for post-operative complications. The nomogram, which included pre-operative albumin and NLR scores, demonstrated superior predictive performance, with a concordance index of 0.821 (95% CI: 0.758–0.883) and improved calibration.
Conclusion: Pre-operative albumin and NLR score are independent risk factors for post-operative complications following colon cancer resection. The developed nomogram incorporating these markers exhibited enhanced predictive capability for post-operative complications.

Keywords: Albumin; Neutrophil-to-lymphocyte ratio; Colon cancer; Nomogram; Post-operative complications; Systemic inflammatory marker

1. Introduction

Colorectal cancer is the third most prevalent cancer and ranks as the second leading cause of cancer-related deaths worldwide.[1] Surgical resection remains the primary therapeutic modality for colon cancer, whether with curative or palliative intent, despite recent advances in radiotherapy and chemotherapy.[2] With the development and widespread adoption of laparoscopic technology, laparoscopic-assisted radical resection of colon cancer has become increasingly favored by gastrointestinal surgeons. This approach has been shown to reduce post-operative pain, accelerate recovery of bowel movement, and reduce the overall patient recovery time compared to traditional open surgery.[3-5] However, post-operative complications continue to be a major factor affecting the prognosis of patients undergoing either laparoscopic-assisted or conventional resection of colon cancer. Early identification and assessment of risk factors for post-operative complications would contribute to informed consent for treatment, consideration of therapeutic modality, and timely multidisciplinary management of high-risk patients.

Previously, studies have reported several perioperative risk factors associated with post-operative complications, including the American Society of Anesthesiologists classification, body mass index, male sex, visceral fat area, type of surgical resection, prolonged operative time, and blood loss.[6-10] A growing number of studies have also revealed that systemic inflammation-based scores were significantly correlated with post-operative complications among patients who underwent various types of surgeries.[11-14] Notably, some researchers demonstrated that the albumin combined with the neutrophil-to-lymphocyte ratio (NLR) score (ANS)–which integrates albumin with an inflammatory indicator–has superior predictive value. The ANS has been shown to play a significant role in predicting post-operative complications and short-term prognosis in patients suffering from gastric or oral cancer.[15,16] To date, however, no study has evaluated the predictive capability of models incorporating ANS for post-operative complications in patients who underwent colon cancer resection.

Nomograms are widely used visual statistical tools in clinical research to predict individual patient outcomes.[16-18] Thus, this present study constructs and validates a predictive nomogram model incorporating ANS to predict post-operative complications in patients who underwent colon cancer resection.

2. Methodology

2.1. Patient selection

We conducted a retrospective study including all patients who underwent colon cancer resection between January 2019 and June 2021 at Sun Yat-sen Memorial Hospital, Sun Yat-sen University. The study's inclusion criteria were: (i) patients aged 18 years or older, (ii) a confirmed diagnosis of colon cancer, (iii) scheduled for elective surgery, and (iv) no prior chemotherapy or immunotherapy. The exclusion criteria of this study were: (i) patients younger than 18 years old, (ii) patients who had received pre-operative chemotherapy or immunotherapy, (iii) patients who underwent conversion from laparoscopic to open surgery, (iv) patients who received rectal resection, (v) patients who had emergency surgeries (defined as emergency surgical treatment within 12 h after admission or after occurrence of related complications), and (vi) patients with incomplete clinical data, defined as missing electronic records pertaining general clinical features, pre-operative laboratory test, intraoperative anesthesia, surgery-related records, and post-operative variables. The study protocol was approved by the Institutional Review Board of Sun Yat-sen Memorial Hospital (No. SYSEC-KY-KS-2021-179) in accordance with the Declaration of Helsinki (as revised in 2013). Due to the retrospective nature of the analysis and all patients having been discharged, informed consent was waived by the institutional review board.

2.2. Data extraction

Data elements were extracted from the hospital's database platforms, including the hospital information system, DoCare anesthesia system, and laboratory information system. The collected variables were categorized as follows:

(i) Patient demographic characteristics: age, sex, and body mass index
(ii) Comorbidities: primary or secondary hypertension, diabetes, coronary artery disease, renal dysfunction, and cerebral infarction
(iii) Pre-operative laboratory indicators: latest test values before surgery, including hemoglobin, albumin, neutrophil, and lymphocyte counts
(iv) Intraoperative anesthesia and surgery-related variables: The American Society of Anesthesiologists status, surgical approach (laparoscopic or open), total crystalloid and colloid infusion, urine output, blood loss, blood transfusion, and duration of surgery
(v) Post-operative variables: post-operative intensive care unit admission, tumor, node, metastases (TNM) staging, length of hospital stay, length of post-operative stay, and post-operative complications.

Post-operative complications included those occurring during hospitalization and categorized as Grade II or higher according to the Clavien-Dindo classification system. These complications encompass both surgical complications–such as anastomotic leakage, intestinal obstruction, post-operative bleeding, and surgical incision infection–and medical complications, including pneumonia, arrhythmia, acute heart failure, thrombosis, and sepsis. The NLR and ANS were calculated for each patient. Cutoff values for albumin and NLR were determined using the Youden index according to a previous study,[19] established at 33.6 g/L and 3.83, respectively. Both low albumin levels and high NLR have been reported as risk factors for post-operative complications.[11,12,20] Accordingly, a value below 33.6 g/L was assigned a score of 1, while levels equal to or above this threshold received a score of 0. Conversely, an NLR exceeding 3.83 was also assigned a score of 1, with lower values receiving a score of 0. The ANS was derived by summing these two parameters: patients with both low albumin and high NLR levels received an ANS score of 2, and patients with high albumin and low NLR levels received a score of 0. An ANS score of 1 was assigned to patients who had either both low albumin level and low NLR, or both high albumin level and high NLR. Thus, ANS scores ranged from 0 to 2. Given that low albumin level or high NLR were independent risk factors for post-operative complications, our study combined these two indicators and adopted the ANS as a core variable. The primary outcome was the occurrence of post-operative complications.

2.3. Univariate and multivariate analysis

The patients were divided into a complication group and a non-complication group according to the occurrence of post-operative surgical or medical complications. Univariate and multivariate logistic regression analyses were performed to identify risk factors associated with post-operative complications. Variables included in the multivariate analysis were selected based on collinearity diagnostics.

2.4. Development and validation of the novel nomograms

The dataset was divided into a training set and a validation set at a 7:3 ratio. This partitioning balances the complexity of model development and the reliability of validation results, while ensuring an adequate number of samples for model training. To establish a novel predictive model, backward stepwise multivariable logistic regression analyses were performed using Akaike's information criterion (AIC) for variable selection, conducted both with and without the inclusion of the ANS. Based on the selected predictors, nomograms were constructed to provide a quantitative instrument estimating the probability of post-operative complications for individual patients. Model performance was assessed using Harrell's concordance (C-index). Calibration curves were plotted to identify the capacity of two novel nomograms predicting the probability of post-operative complications. The bootstrapping validation was conducted (1000 bootstrap resamples) to compute a comparatively corrective C-index in the original cohort. The calibration curves and C-indices were contrasted to evaluate the predictive effectiveness between the two novel nomogram models.

2.5. Statistical analyses

Continuous variables conforming to a normal distribution were presented as means ± standard deviation and compared using Student's *t*-test. Variables not normally distributed were expressed as medians with interquartile ranges and analyzed using the Mann-Whitney *U*-test. Categorical data were described as numbers and percentages and assessed using Pearson's Chi-square test or Fisher's exact test, depending on the frequencies of the data. Univariable and multivariate logistic analyses were performed using IBM Statistical Package for Social Sciences software (version 22.0). The development and validation of nomograms were conducted using R software (version 3.4.2; http://www.Rproject.org, "rms" R package). Statistical significance was determined at $p<0.05$.

3. Results

3.1. Patients and general clinical characteristics

Medical records of 485 patients who underwent colon cancer resection from January 2019 to June 2021 were retrospectively collected from the database platform. Fifteen patients were excluded due to missing pre-operative examination indicators (hemoglobin and neutrophils, $n = 1$), intraoperative anesthesia, and surgery-related variables (urine output [$n = 8$], blood loss [$n = 4$], and duration of surgery [$n = 2$]). A total of 42 patients were excluded due to a combination of other types of surgery or pre-operative complications. Finally, this study enrolled 428 patients and randomly assigned 301 patients to the primary cohort and 127 patients to the validation cohort to construct a predictive model. Post-operative complications occurred in 64 patients (14.95%), including anastomotic leakage ($n = 17$, 3.97%), surgical incision infection ($n = 6$, 1.40%), post-operative bleeding ($n = 10$, 2.34%), intestinal obstruction ($n = 12$, 2.80%), pneumonia ($n = 5$, 0.93%), sepsis ($n = 4$, 0.93%), thrombosis ($n = 4$, 0.93%), arrhythmia ($n = 2$, 0.47%), and acute heart failure ($n = 4$, 0.93%) (Table 1).

As shown in Table 2, compared to the non-complication group, patients in the complication group were more likely to be male (68.75% vs. 55.22%; p=0.044) and were older (68.16 ± 13.60 vs. 61.68 ± 12.31; p<0.001). They also exhibited a higher clinical TNM stage, with 95.31% at stage III-IV compared to 84.49% in the non-complication group (p=0.021), and a higher ANS score (ANS = 2: 25.00% vs. 6.87%; p<0.001). Moreover, patients in the complication

Table 1. Types of post-operative complications

Post-operative complications	Number of patients, (*n*, %)
Surgical	
Anastomotic leakage	17 (3.97)
Surgical incision infection	6 (1.40)
Post-operative bleeding	10 (2.34)
Intestinal obstruction	12 (2.80)
Medical	
Pneumonia	5 (0.93)
Sepsis	4 (0.93)
Thrombosis	4 (0.93)
Arrhythmia	2 (0.47)
Acute heart failure	4 (0.93)
Total	64 (14.95)

group experienced greater volume of intraoperative blood loss (70.00 [50.00–125.00] vs. 50.00 [30.00–100.00]; p=0.001), and a higher intraoperative transfusion rate (57.81% vs. 21.45%; p<0.001). They also received a larger volume of total crystalloid (1018.73 ± 500.79 vs. 854.32 ± 382.09; p=0.003), and underwent longer surgical procedures (4.29 ± 1.78 vs. 3.41 ± 1.07; p<0.001). Postoperatively, patients in the complication group had increased rates of intensive care unit admission (26.56% vs. 2.48%; p<0.001), as well as longer length of hospital stay (20.50 [15.00–32.75] vs. 13.00 [10.00–15.00]; p<0.001) and post-operative stay (13.00 [9.00–24.00] vs. 7.00 [6.00–8.00]; p<0.001). In addition, patients in the complication group had a higher rate of open surgery (34.92% vs. 10.53%; p<0.001).

3.2. Univariable and multivariable analysis between the complication and non-complication groups in the primary cohort

The univariate and multivariate logistic regression analyses between the complication and non-complication groups in the primary cohort are shown in Table 3. The univariate logistic regression analyses suggested that the following were significantly correlated with post-operative complications: age, pre-operative hemoglobin, pre-operative ANS, surgical type, intraoperative transfusion, total crystalloid, and duration of surgery. Multivariate logistic regression analysis showed significant correlations between the incidence of post-operative complications and age, pre-operative ANS, intraoperative transfusion, and duration of surgery after adjusting for the effect of other covariates.

3.3. Model development

Backward stepwise AIC-based multivariable analysis identified age, duration of surgery, intraoperative

Table 2. Baseline characteristics of participants

Characteristics	No complication (*n*=364)	Complication (*n*=64)	*p*-value
Gender (male)	201 (55.22)	44 (68.75)	0.044
Age (years; mean±SD)	61.68±12.31	68.16±13.60	<0.001
Body mass index (kg/m²; mean±SD)	22.73±4.73	22.04±4.54	0.529
ASA status			0.117[a]
II	205 (56.32)	28 (43.75)	
III	155 (42.58)	35 (54.69)	
IV	4 (1.10)	1 (1.56)	
Clinical TNM stage			0.015[a]
I-II	202 (55.49)	25 (39.06)	
III-IV	162 (44.51)	39 (60.94)	
Co-morbidities	135 (45.05)	22 (34.38)	0.678
Pre-operative hemoglobin (g/L; mean±SD)	119.70±47.83	113.77±27.69	0.336
Pre-operative ANS			<0.001
0	236 (64.84)	30 (46.88)	
1	103 (28.30)	18 (28.12)	
2	25 (6.87)	16 (25.00)	
Surgical type			<0.001
Laparoscopic	326 (89.56)	43 (67.19)	
Open	38 (10.44)	21 (32.81)	
Intraoperative blood loss (mL; median [IQR])	50.00 (30.00–100.00)	70.00 (50.00–125.00)	0.001[a]
Intraoperative transfusion	77 (21.45)	37 (57.81)	<0.001
Total crystalloid (mL; mean±SD)	854.32±382.09	1018.73±500.79	0.003
Total colloid (mL; median [IQR])	1000.00 (500.00–1000.00)	1000.00 (500.00–1000.00)	0.073[a]
Urine output (mL; median [IQR])	450.00 (300.00–700.00)	400.00 (300.00–600.00)	0.575
Duration of surgery (hours; mean±SD)	3.41±1.07	4.29±1.78	<0.001
Post-operative ICU admission	9 (2.48)	17 (26.56)	<0.001[a]
Length of hospital stay (days; median [IQR])	13.00 (10.00–15.00)	20.50 (15.00–32.75)	<0.001[a]
Length of post-operative stay (days; median [IQR])	7.00 (6.00–8.00)	13.00 (9.00–24.00)	<0.001[a]

Notes: [a]Mann-Whitney *U* test for continuous variables, Fisher's exact test for categorical variables with expectations <10. Data are presented as *n* (%) unless stated otherwise.
Abbreviations: ANS: Albumin/neutrophil-to-lymphocyte ratio score; ASA: American Society of Anesthesiologists; ICU: Intensive care unit; IQR: Interquartile range; SD: Standard deviation; TNM: Tumor, node, metastasis.

Table 3. Univariate and multivariate logistic regression analyses of the factors associated with post-operative complications in the primary cohort

Characteristics	No complication (*n*=254)	Complication	Univariate		Multivariate	
			OR (95% CI)	*p*	OR (95% CI)	*p*
Gender (male)	140 (55.12)	30 (63.83)	0.70 (0.37–1.33)	0.270	-	-
Age (years; mean±SD)	61.59±12.14	67.47±14.00	1.04 (1.01–1.07)	0.004	1.05 (1.01–1.09)	0.007
Body mass index (kg/m^2; mean±SD)	22.37±4.65	22.14±4.31	1.002 (0.054–1.184)	0.285	-	-
ASA status						
II	145 (57.09)	21 (44.68)	Reference	-	-	-
III	106 (41.73)	25 (53.19)	1.63 (0.87–3.06)	0.343	-	-
IV	3 (1.18)	1 (2.13)	2.30 (0.23–23.16)	0.479	-	-
Clinical TNM stage						
I-II	41 (16.14)	3 (6.38)	Reference	-	Reference	-
III-IV	213 (83.86)	44 (93.62)	2.82 (0.84–9.53)	0.094	1.85 (0.48–7.16)	0.371
Comorbidities	117 (46.06)	25 (53.19)	1.33 (0.71–2.48)	0.369	-	-
Pre-operative hemoglobin (g/L; mean±SD)						
<80	19 (7.48)	8 (17.02)	Reference	-	Reference	-
80–<90	23 (9.06)	6 (12.77)	0.62 (0.18, 2.10)	0.442	0.85 (0.20–3.66)	0.823
90–<100	22 (8.66)	3 (6.38)	0.32 (0.08, 1.40)	0.131	0.43 (0.07–2.55)	0.350
100–<110	17 (6.69)	3 (6.38)	0.42 (0.10, 1.84)	0.249	1.22 (0.18–8.49)	0.840
110–<120	37 (14.57)	5 (10.64)	0.32 (0.09, 1.12)	0.074	1.90 (0.35–10.28)	0.455
>120	136 (53.54)	22 (46.81)	0.38 (0.15, 0.98)	0.046	2.36 (0.57–9.76)	0.237
Pre-operative ANS						
0	162 (63.78)	21 (46.88)	Reference	-	Reference	-
1	68 (26.77)	13 (27.66)	1.18 (1.01–1.38)	0.035	0.71 (0.28–1.77)	0.46
2	24 (9.45)	13 (27.66)	0.95 (0.62–1.47)	0.830	2.69 (1.90–8.06)	0.01
Surgical type						
Laparoscopic	225 (88.58)	33 (70.21)	Reference	-	Reference	-
Open	29 (11.42)	14 (29.79)	1.003 (1.001–1.006)	0.022	1.90 (0.73–4.92)	0.189
Intraoperative blood loss (mL; median [IQR])	50.00 (30.00–100.00)	100.00 (50.00–100.00)	1.001 (0.999–1.004)	0.300	-	-
Intraoperative transfusion	55 (21.65)	28 (59.57)	1.007 (1.002–1.013)	0.015	5.32 (1.87–15.15)	0.002
Total crystalloid (mL; mean±SD)	1,000.00 (500.00–1,000.00)	1,000.00 (500.00–1,000.00)	1.002 (1.000–1.003)	0.011	0.9996 (0.9985–1.0008)	0.525
Total colloid (mL; median [IQR])	1,000.00 (500.00–1,000.00)	1,000.00 (500.00–1,000.00)	0.9999 (0.99998–1.0000)	0.107	0.9997 (0.9985–1.0008)	0.570
Urine output (mL; median [IQR])	500.00 (300.00–700.00)	400.00 (300.00–650.00)	0.95 (0.90–1.00)	0.950	-	-
Duration of surgery (hours; mean±SD)	3.37±1.05	4.31±1.75	1.002 (1.001–1.004)	0.045	1.70 (1.24–2.34)	0.001

Note: Data are presented as *n* (%) unless stated otherwise.
Abbreviations: ANS: Albumin/neutrophil-to-lymphocyte ratio score; ASA: American Society of Anesthesiologists; CI: Confidence interval; ICU: Intensive care unit; IQR: Interquartile range; OR: Odds ratio; SD: Standard deviation; TNM: Tumor, node, metastasis.

transfusion, and surgical type as independent risk factors for post-operative complications when ANS was not included in the analysis (Table 4). However, when ANS was included in the backward stepwise analysis, sex, age, ANS, duration of surgery, urine output, intraoperative transfusion, and surgical type were identified as independent risk factors for post-operative complications (Table 4). The above independent predictors were used to develop Model 1 (nomogram without ANS) and Model 2 (nomogram with ANS) (Figure 1).

3.4. Model validation

In the primary cohort, the C-index of Model 1 (nomogram without ANS) was 0.798 (95% confidence interval [CI]: 0.729–0.868). In the validation cohort, the C-index was 0.832 (95% CI: 0.767–0.938). However, when the nomogram was combined with ANS (Model 2), a higher C-index was observed in both the primary (0.821; 95% CI: 0.758–0.883) and validation cohorts (0.853; 95% CI: 0.746–0.961). The difference in C-statistics was statistically significant (ΔC = 0.02; 95% CI: 0.01–0.04; p=0.008 using the DeLong test) in the validation cohorts. Subsequently, calibration curves were constructed to evaluate the calibration (Figure 2). The calibration curves also illustrated that, compared to Model 1 (Figure 2A and C), Model 2 demonstrated better accordance between the observed occurrence of post-operative complications and the nomogram predictions (Figure 2B and D). In addition, the net reclassification improvement compared between the two models was 0.147 (95% CI: 0.021–0.274; p=0.018), indicating that Model 2 has better predictive accuracy than Model 1.

Table 4. Risk factors for post-operative complications derived from Akaike's information criterion-based multivariate logistic regression analysis

Characteristic	Model 1		Model 2	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Gender male	NA	NA	0.58 (0.27–1.24)	0.160
Age (years)	1.036 (1.006–1.069)	0.019	1.036 (1.004–1.067)	0.026
Albumin/neutrophil-to-lymphocyte ratio score				
0	NA	NA	Reference	
1	NA	NA	0.64 (0.27–1.52)	0.310
2	NA	NA	2.22 (1.85–5.76)	0.002
Surgery types				
Laparoscopy	Reference	-	Reference	-
Open	2.22 (0.98–5.04)	0.057	2.19 (0.94–5.12)	0.069
Urine output (mL)	NA	NA	0.9991 (0.9978–1.0003)	0.138
Intraoperative blood transfusion	3.29 (1.62–6.69)	0.001	3.07 (1.46–6.47)	0.003
Duration of surgery (hours)	1.59 (1.23–2.05)	<0.001	1.69 (1.28–2.24)	<0.001

Abbreviations: CI: Confidence interval; NA: Not available; OR: Odds ratio.

4. Discussion

In the present study, we demonstrated that pre-operative ANS was an independent risk factor for post-operative complications in patients who underwent radical colon cancer resection. Building upon this finding, we constructed and validated a prognostic nomogram incorporating the ANS alongside established perioperative risk factors to predict post-operative complications. This visual nomogram offers a practical tool for more precise risk stratification of post-operative complications for individual patients, which may facilitate early clinical decision-making. According to the nomogram analysis, patients with a pre-operative ANS score of 2, characterized by pre-operative albumin levels below 33.6 g/L and NLR values exceeding 3.83, are at a significantly heightened risk for post-operative complications. Consequently, it is imperative to address hypoalbuminemia and mitigate inflammatory responses in these individuals before elective surgical procedures.

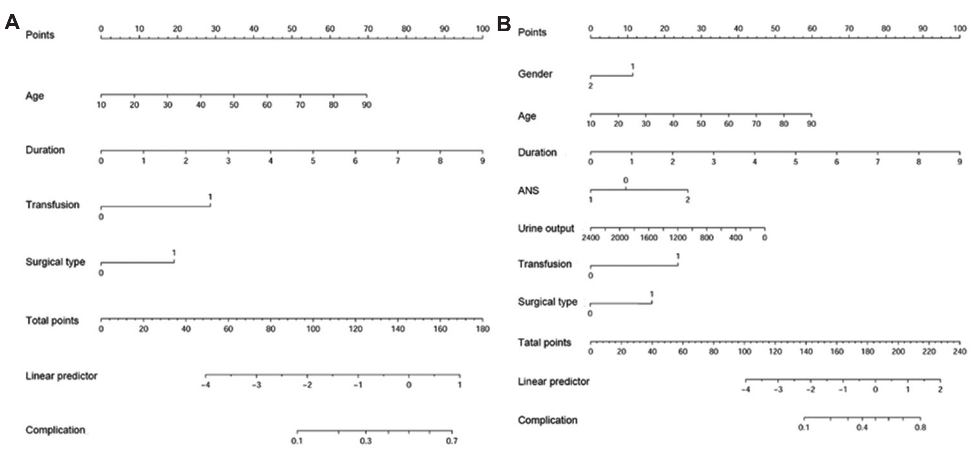

Figure 1. Nomograms derived from Akaike's information criterion-based multivariate analyses. (A) The nomogram without albumin/neutrophil-to-lymphocyte ratio score (ANS). (B) The nomogram incorporating ANS.

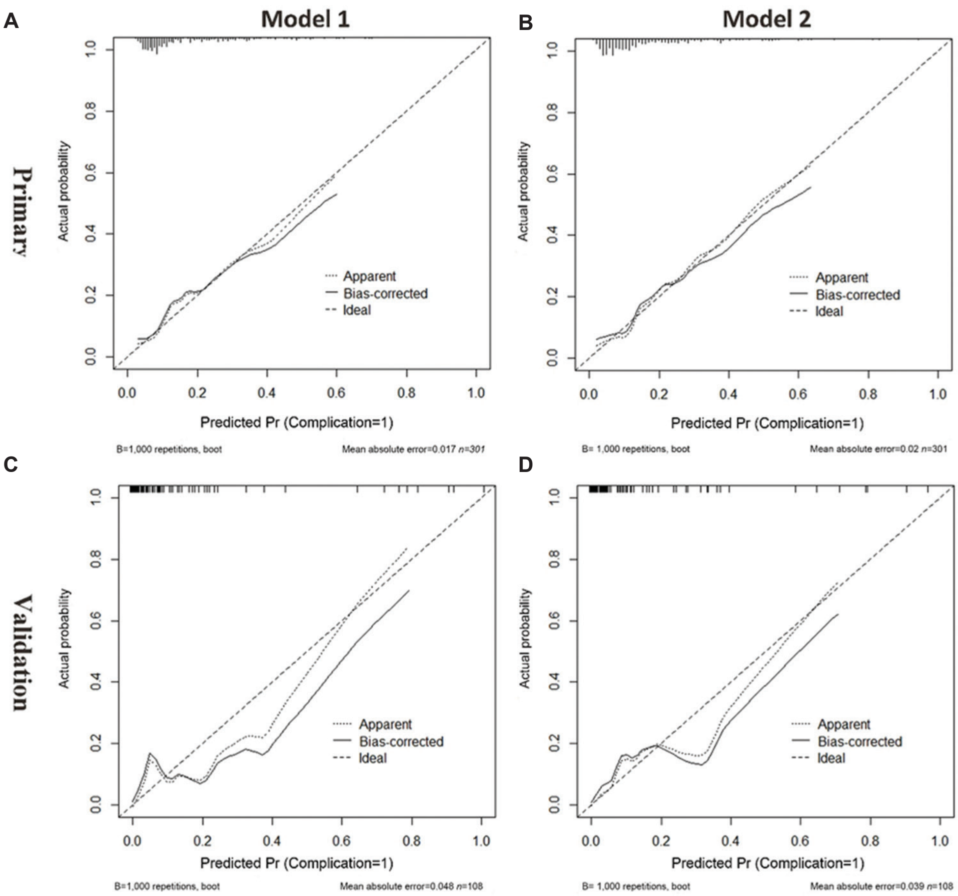

Figure 2. Calibration curves of nomograms. Calibration curves of Model 1 and Model 2 in the primary (A and B) and validation cohorts (C and D).

Specifically, previous studies revealed that various immunonutrition- and inflammation-based scores, including C-reactive protein (CRP) to albumin ratio, NLR, platelet-to-lymphocyte ratio, and prognostic nutritional index, were associated with short-term outcomes after surgery in patients with colorectal cancer.[21-24] However, the variability in cut-off values for inflammatory markers across studies hinders their clinical utility. Furthermore, there is a paucity of evidence comparing the predictive values of different inflammatory markers for post-operative complications following radical colon cancer resection. In addition to various ratios based on circulating blood cell counts, several inflammation-based scoring systems have been developed to enhance risk prediction for individual patients. The Modified Glasgow Prognostic Score, which incorporates both CRP and albumin levels, was frequently employed. A recent study has indicated that the NLR may exhibit superior sensitivity and specificity in predicting post-operative complications compared to CRP.[25] In addition, previous research demonstrated that NLR, as opposed to platelet-to-lymphocyte ratio and prognostic nutritional index, was a significant predictor of severe post-operative complications following pancreaticoduodenectomy.[19] In the present study, the association between ANS and post-operative complications after radical colon cancer resection was determined. The NLR is a well-established systemic inflammation biomarker readily calculated from routinely obtained pre-operative complete blood counts at no additional cost. Hypoalbuminemia, often reflecting malnutrition, is common among cancer patients and is correlated with an increased risk of post-operative infectious complications, likely due to impaired wound healing and compromised immune function.[26,27] By combining these two indicators, the ANS simultaneously reflects hepatic inflammatory status (via albumin) and systemic immune activation (via NLR), providing a more comprehensive assessment of the patient's inflammatory and nutritional state than either marker alone. Therefore, incorporating the ANS into predictive models enhances the ability to identify patients at higher risk for adverse post-operative outcomes.

In the present study, pre-operative ANS was identified as an independent risk factor for post-operative complications after radical colon cancer resection. The nomogram incorporating ANS demonstrated superior discriminative ability with a C-index of 0.821 based on the AIC-based multivariable analysis, compared to a C-index of 0.798 for the model excluding ANS. The calibration curve also demonstrated that using ANS could significantly enhance the predictive value of the nomogram for radical colon cancer resection. Albumin is a well-recognized negative acute-phase protein whose serum levels decline during inflammatory states. Hypoalbuminemia generally reflects malnutrition in both acutely and chronically ill patients. Previous studies have also demonstrated that hypoalbuminemia is a significant risk factor for post-operative mortality, morbidity, and length of hospital stay in patients.[28,29] Although the mechanistic link between inflammation and short-term poor prognosis remains incompletely understood, our study supports the clinical utility of pre-operative ANS as an independent risk factor for post-operative complications after radical colon cancer resection.

Apart from ANS, intraoperative blood transfusion was identified as another independent risk factor for post-operative complications after radical colon cancer resection in the backward stepwise AIC-based multivariable analysis. Previous studies demonstrated that blood transfusion was correlated with an increasing occurrence of post-operative infections around anastomoses, likely due to transfusion-associated immunological suppression.[30-32] In addition, Jannasch *et al*.[33] indicated that there was a 1.5-fold risk of anastomotic leakage in patients receiving blood transfusions during radical colon cancer resections, though the effect of transfusion volume was not specified.[33] While blood transfusion may be a risk factor for post-operative complications, it is an essential component of perioperative fluid management for surgical patients. Thus, judicious application of blood transfusion guidelines is necessary to minimize unnecessary blood transfusions and thereby reduce the risk of post-operative complications.

In addition to ANS and blood transfusion, other variables, including sex, age, duration of surgery, urine output, and surgical type, were also included in the nomogram model. The combination of these variables in our nomogram enhanced its predictive value, which further indicated the critical roles of these variables in forecasting the probability of post-operative complications after radical colon cancer resection.

Nevertheless, the present study had several limitations. Statistical models were developed based on a retrospective study conducted at a single center. In this regard, future prospective research is needed to verify the outcomes. In addition, external dataset validation was not performed, underscoring the need for broader model testing across diverse populations. Different surgical groups should be considered in future studies, as surgical manipulation may have a significant impact on patients' short-term outcomes.

5. Conclusion

This study developed and validated a nomogram combining albumin and NLR with other perioperative risk factors to predict post-operative complications in patients who underwent colon cancer resection. This nomogram indicated the significant role of systemic inflammation in predicting post-operative complications. Moreover, surgeons could now utilize this novel model to better estimate an individual patient's complication risk and make more informed, personalized clinical decisions regarding pre-operative management.

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Conflict of interest

The authors declare no competing interests in this article.

Author contributions

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Ethics approval and consent to participate

The study approval was obtained from the Institutional Review Board of Sun Yat-sen Memorial Hospital of Sun Yat-sen University (No. SYSEC-KY-KS-2021-179). Given the retrospective nature of the analysis, patient informed consent was waived.

Consent for publication

Given the retrospective nature of the analysis, patient informed consent for publication was waived.

Availability of data

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

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