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Original Article

Clinical value of prognostic nutritional index combined with C-reactive protein and albumin in early prediction of anastomotic leakage after radical gastric cancer surgery

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Abstract: Objective: To evaluate the predictive value of the Prognostic Nutritional Index (PNI) combined with C-reactive protein (CRP) and albumin (ALB) for anastomotic leakage following radical gastric cancer surgery. Methods: A retrospective case-control study was conducted with 275 gastric cancer patients at the Second People's Hospital of Lanzhou City from September 2019 to October 2022. Patients were categorized into an anastomotic leakage group (n=31) or a non-leakage group. Clinical, surgical, and pathological data were analyzed using logistic regression to develop two risk models: a combined clinical-laboratory index (RISK1) and a separate laboratory index (RISK2). Model effectiveness was compared using Receiver Operating Characteristic (ROC) curves. Results: Anastomotic leakage occurred in 11.27% of patients, predominantly in those with advanced TNM stages (P=0.006). Notably, higher operative times (P=0.049) and increased intraoperative bleeding (P=0.027) were associated with the leakage group. Significant differences in ALB, PNI, and CRP levels were observed between the groups. Both RISK1 and RISK2 identified ALB, CRP, PNI, operative time, and intraoperative bleeding as independent predictors of leakage, demonstrating high predictive accuracy (RISK1 AUC=0.937, RISK2 AUC=0.911), with no significant difference in performance between the models (P=0.245). Conclusion: The combination of ALB, CRP, and PNI effectively predicts the risk of anastomotic leakage in patients undergoing gastric cancer surgery. These biomarkers can significantly enhance postoperative management and improve patient outcomes.

Keywords: Prognostic nutritional index, CRP, ALB, radical gastric cancer surgery, postoperative anastomotic leakage

Introduction

Gastric cancer is the fifth most common malignancy worldwide and the third leading cause of cancer-related mortality. In China, the incidence and mortality rates of gastric cancer are notably high, ranking third (10.6%) and second (13.6%), respectively [1]. The disease often progresses without noticeable symptoms in its early stages, leading to late diagnoses. This problem is exacerbated by uneven distribution of medical resources, causing many patients to miss the optimal treatment window [2]. These challenges highlight the critical need for improved early detection methods and more equitable healthcare access to better patient outcomes.

Treatment for gastric cancer primarily involves surgery, frequently complemented by chemotherapy. Surgical techniques have progressed from traditional open methods to minimally invasive procedures, including laparoscopic and robotic surgeries [3]. Complications post-radical surgery range from 13.0% to 30.3%, with anastomotic leakage being one of the most severe, occurring in 0.5% to 15% of cases [4, 5]. This complication can significantly impact

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patient prognosis by increasing hospital stays, healthcare costs, and the need for further surgeries, and in severe cases, it can be life-threatening [6, 7].

Risk factors for anastomotic leakage include advanced age, obesity, diabetes mellitus, poor anastomotic blood supply, and excessive tension at the anastomotic site [8, 9]. Preventive measures emphasize the importance of preoperative nutritional assessments, surgical expertise, careful intraoperative management, and ensuring adequate blood supply to the anastomosis to reduce leakage risk. Prompt diagnosis and management are crucial for addressing this complication effectively [10].

While traditional markers such as white blood cell count [11], C-reactive protein (CRP) [12], and calcitonin are commonly used to predict anastomotic leakage, there is a persistent need for more effective predictive models for postoperative management in gastric cancer patients. The Prognostic Nutritional Index (PNI), determined by serum albumin levels and peripheral blood lymphocyte counts, reflects a patient's nutritional status and immune function [13]. Lower PNI values indicate poorer prognosis and an increased risk of postoperative complications. Elevated CRP levels typically indicate inflammation or infection, while low albumin levels are associated with poor recovery and a heightened risk of complications [14, 15]. This evidence highlights the importance of comprehensive preoperative and postoperative management strategies to improve outcomes in gastric cancer surgery.

Given the significant impact of anastomotic leakage on prognosis, this study aims to develop an efficient predictive model by evaluating nutritional and inflammatory markers to accurately assess risk. This model strives to provide a clear and precise tool for predicting the risk of postoperative anastomotic leakage, thereby enhancing patient management and improving outcomes.

Methods and data

Clinical information

This retrospective study analyzed gastric cancer patients admitted to the Second People's Hospital of Lanzhou City from September 2019 to October 2022. Patients were categorized based on the occurrence of anastomotic leakage within one week post-surgery and put into one of two groups: those with or without leakage. The study received approval from the ethical committee of The Second People's Hospital of Lanzhou City (**Figure 1**).

Inclusion criteria: (1) Confirmed diagnosis of gastric cancer through preoperative pathological examination of digestive endoscopic biopsy samples (n=624). (2) Underwent radical gastric cancer surgery with D2 lymph node dissection (n=545). (3) Postoperative pathological confirmation of gastric cancer diagnosis (n=484). (4) Availability of complete medical records (n=408).

Exclusion criteria: (1) Patients who underwent emergency surgery due to gastric perforation or bleeding (n=381). (2) Presence of distant metastasis or lesions infiltrating neighboring organs as revealed by imaging or intraoperative exploration (n=365). (3) Patients who received preoperative radiation therapy, chemotherapy, or long-term use of immunosuppressants or nonsteroidal anti-inflammatory drugs (n=318). (4) Necessity for intraoperative combined resection of other organs, such as the tail of the pancreas or spleen, or if only palliative resection was performed (n=300). (5) Presence of other postoperative infectious complications (n=294). (6) Patients undergoing postoperative peritoneal heat infusion chemotherapy (n=281). (7) Development of an anastomotic leak on the first postoperative day (n=275).

Definition of anastomotic leak

The International Society for Gastric Cancer defines anastomotic leakage as a full-thickness defect occurring at the site of esophagojejunal, gastrojejunal, or jejunojejunal anastomoses. Confirmed typically within one week postoperatively, this definition includes physical breaches and peri-anastomotic abscesses, and categorizes duodenal and gastric stump leaks as anastomotic leaks. This broad categorization is made independent of clinical manifestations, differential diagnoses, prognostic outcomes, or treatment methodologies [16].

Sample information acquisition

Data for this study was sourced from the hospital's medical research big data platform and

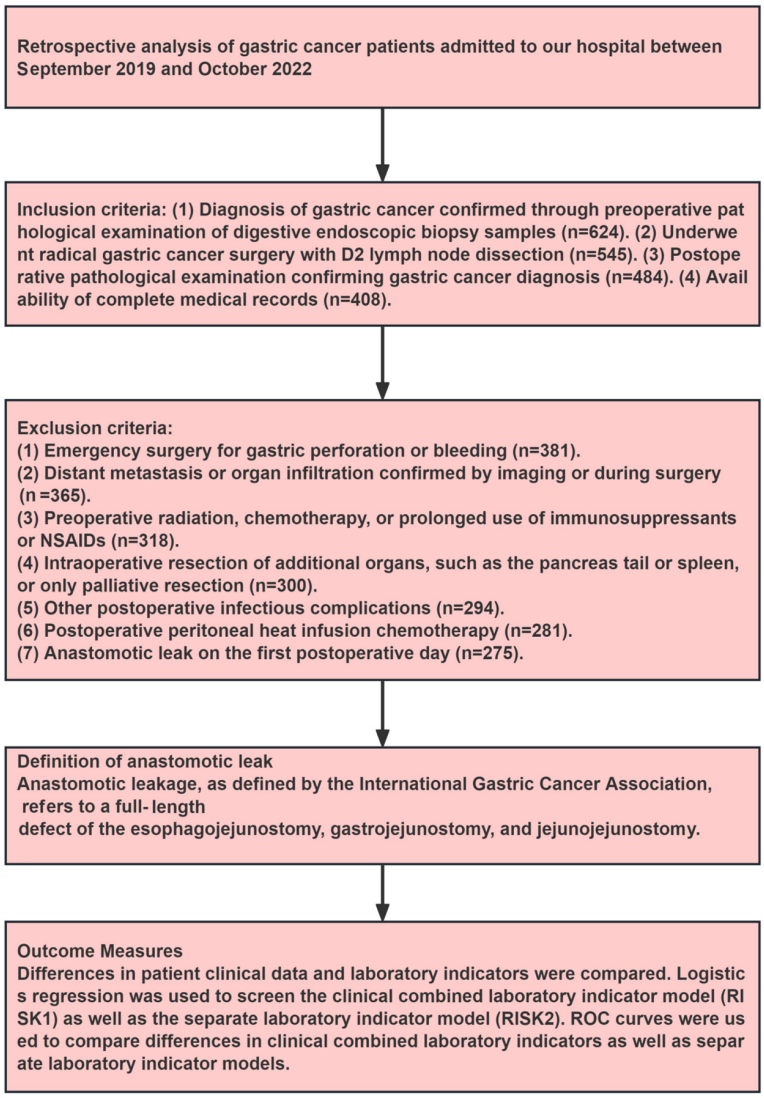

Figure 1. Study flowchart. NSAIDs, Nonsteroidal anti-inflammatory drugs.

the hospital information management system. A total of 275 cases were analyzed, including 31 patients with anastomotic leakage and 244 without. Collected clinical data included age, gender, body mass index, history of hypertension, diabetes, cardiac and pulmonary insufficiency, pyloric obstruction, tumor diameter, surgical approach, gastrectomy extent, anastomosis approach, combined organ resection, and Tumor, Node, Metastasis (TNM) staging [17]. Operative time and intraoperative bleeding were also recorded. Laboratory parameters measured on the first postoperative day included Albumin (ALB), Lymphocytes (LYM), C-reactive protein (CRP), Prognostic Nutritional Index (PNI), C-reactive protein/Albumin Ratio (CAR), Carcinoembryonic antigen (CEA), and Carbohydrate antigen 242 (CA242). The PNI calculation was ALB (g/L) + 5 × LYM (× 10^9/L); CAR was determined as CRP/ALB. ALB was analyzed using an automated biochemistry analyzer (Beckman Coulter, AU5800), CRP was measured by a protein-specific immunoassay analyzer (Myeri, CRP-M100), LYM by a fully automated blood cell analyzer (Myeri, BC-6800), and CEA and CA242 by double-antibody enzyme-linked immunosorbent assay (ELISA Bio mI038471, mI057568).

Outcome measures

Differences in clinical data and laboratory indicators between groups were analyzed. Logistic regression was utilized to develop the combined clinical-laboratory indicator model (RISK1) and the separate laboratory indicator model (RISK2). Receiver Operating Characteristic (ROC) curves compared the effectiveness of these models.

Statistical analysis

Data were visualized and analyzed using GraphPad Prism 9. Continuous data were expressed as mean ± standard deviation and compared using the t-test for normally distributed data, expressed as t. Non-normally distributed data were assessed using the rank-sum test, expressed as Z. Categorical data were expressed as percentages (%) and analyzed using the chi-square test, expressed as χ^2. The clinical utility was evaluated using the ROC curve, and differences in the area under the ROC curve were analyzed using the DeLong test. Logistic regression was employed to identify predictors of anastomotic leakage following radical gastric cancer surgery. A p-value <0.05 was considered statistically significant.

Results

Comparison of baseline information

Anastomotic leakage occurred in 31 patients, representing an incidence of 11.27%. Patients with anastomotic leakage had a significantly higher prevalence of advanced TNM stages compared to those without leakage (P=0.006). Additionally, the operation time (P=0.049) and intraoperative bleeding (P=0.027) were significantly greater in the leakage group compared to the non-leakage group (**Table 1**).

Comparison of tumor markers and nutrition-related indicators

A comparison of tumor markers and nutrition-related indicators between the two groups revealed significantly lower levels of ALB and PNI (both P<0.001) in the anastomotic leakage group compared to the non-leakage group. Conversely, CRP (P<0.001) and CAR (both P<0.001) were significantly higher in the anastomotic leakage group, indicating statistically significant differences (**Table 2**).

Screening of characterization factors to predict anastomotic leakage

Logistic regression was employed to construct models for predicting anastomotic leakage in patients. Initial steps included assigning values to meaningful characterization factors (**Table 3**). Two prediction models were developed, one based on meaningful laboratory indicators combined with clinical data and another based solely on laboratory indicators. Multifactorial analysis with combined clinical data identified ALB (P=0.012), CAR (P<0.001), operative time (P=0.014), and intraoperative bleeding (P=0.011) as independent predictors of anastomotic leakage (**Table 4**). A separate analysis using only laboratory indices found ALB (P=0.005), CRP (P<0.001), and PNI (P=0.015) as independent predictors (**Table 5**).

Construction and comparison of anastomotic leakage models

Two prediction models were constructed using the beta coefficients and constants from the regression analyses. The risk formula for RISK1 is: ALB * -2.003 + CAR * 3.145 + operative time * 1.499 + intraoperative bleeding * 1.734 + constant * -3.581. RISK2 = ALB * -1.968 * CRP * 2.707 * PNI * -2.073 * constant * -1.19. Comparison of patient scores revealed that those in the anastomotic leakage group scored higher on both models than those in the non-leakage group (**Figure 2A**, P<0.001). ROC curves plotted for both models showed the area under the curve for RISK1 at 0.937, and for RISK2 at 0.911 (**Figure 2B**; **Table 6**). The DeLong test indicated no statistical difference in the performance between RISK1 and RISK2 (Z=1.164, P=0.245).

Discussion

Gastric cancer, globally recognized as one of the most common malignant tumors, remains a leading cause of cancer-related mortality [18]. Surgical interventions such as total gastrectomy, proximal gastrectomy, and distal gastrectomy with lymph node dissection are crucial for the radical treatment of this disease [19]. However, anastomotic leakage, a significant postoperative complication, negatively impacts patient outcomes and is a key prognostic indicator of poor prognosis [20]. These leaks typically manifest between 5 to 7 days post-operation and are challenging to predict early due to subtle initial symptoms, complicating early diagnosis and effective management of anastomotic leaks [10].

In the realm of risk prediction for anastomotic leakage following gastric cancer surgery, contemporary models combine extensive clinical data and laboratory metrics for a comprehensive risk assessment. Maejima et al. identified advanced age, male gender, diabetes mellitus, and blood loss ≥1,100 g as independent risk factors for esophagojejunal anastomotic leakage [7]. Shi et al. developed a prediction scoring system (AScore-POD3) with an AUC of 0.83 at three days postoperatively, demonstrating predictive accuracy [20]. However, these models, requiring the collection and analysis of multiple variables, can complicate clinical workflows and lengthen data processing times, limiting their practical utility in urgent scenarios [21]. Conversely, models using a single indicator or a limited set of indicators offer a simpler and more rapid predictive approach, particularly valuable in resource-limited settings [22].

Table 1. Comparison of clinical data

Maker	Anastomotic leakage group (n=31)	No anastomotic leakage group (n=244)	χ^2/t/Z value	*P*-value
Age				
≥65 years	18	161	0.759	0.384
<65 years	13	83		
Distinguishing between the sexes				
Male	19	127	0.943	0.331
Women	12	117		
Body mass index				
≥25 kg/m^2	8	78	0.486	0.486
<25 kg/m^2	23	166		
History of hypertension				
Yes	7	68	0.388	0.533
No	24	176		
History of diabetes				
Yes	8	49	0.549	0.459
No	23	195		
Cardiac insufficiency				
Yes	2	24	0.368	0.544
No	29	220		
Pulmonary insufficiency				
Yes	4	44	0.502	0.478
No	27	200		
Pyloric obstruction				
Yes	2	7	1.115	0.291
No	29	237		
Tumor diameter				
≥3 cm	17	166	2.151	0.142
<3 cm	14	78		
Surgical Procedures				
Open the abdomen	11	110	1.028	0.311
Laparoscopy	20	134		
Extent of Gastrectomy				
Distal resection	21	142	1.038	0.308
Else	10	102		
Anastomosis				
Billroth-I anastomosis	6	45	0.02	0.990
Billroth-II anastomosis	12	94		
Roux-en-Y match	13	105		
Combined organ removal				
Yes	4	20	0.765	0.382
No	27	224		
Degree of tumor differentiation				
Low polarization	18	110	1.863	0.172
Medium + High differentiation	13	134		
TNM staging				
I	5	77	10.253	0.006
II	5	75		
III	21	92		
Surgical time (min)	287.00 [249.50, 336.00]	262.50 [226.00, 307.25]	1.968	0.049
Intraoperative Bleeding (mL)	428.06±54.52	404.39±47.04	2.311	0.027

Note: TNM, Tumor, Node, Metastasis.

Table 2. Tumor markers and nutritional indicators

Maker	Anastomotic leakage group (n=31)	No anastomotic leakage group (n=244)	χ^2/t/Z value	*P*-value
ALB (g/L)	27.56±3.63	33.59±3.91	-8.637	<0.001
LYM (10*9/L)	1.54±0.36	1.60±0.36	-0.967	0.340
CRP (μg/L)	58.07 [37.75, 68.56]	33.72 [20.36, 46.72]	4.452	<0.001
PNI	35.24±3.98	41.60±4.21	-8.323	<0.001
CAR	2.00 [1.22, 2.47]	1.03 [0.60, 1.39]	5.474	<0.001
CEA (ng/mL)	18.72±5.39	18.69±4.99	0.023	0.982
CA242 (kU/L)	18.98±2.23	19.35±3.49	-0.826	0.412

Note: ALB, Albumin; LYM, Lymphocyte; CRP, C-reactive protein; PNI, Prognostic Nutritional Index; CAR, C-reactive protein/Albumin Ratio; CEA, Carcinoembryonic antigen; CA242, Carbohydrate antigen 242.

Table 3. Assignment table

Considerations	Assign a value to something
Surgical time (min)	≥311.500=1, <311.500=0
Intraoperative Bleeding (mL)	≥404.500=1, <404.500=0
ALB (g/L)	≥30.140=1, <30.140=0
CRP (μg/L)	≥55.665=1, <55.665=0
PNI	≥39.285=1, <39.285=0
CAR	≥1.967=1, <1.967=0
TNM staging	I=0, II=1, III=2
Anastomotic leakage	Yes =1, No =0

Note: ALB, Albumin; LYM, Lymphocyte; CRP, C-reactive protein; PNI, Prognostic Nutritional Index; CAR, C-reactive protein/Albumin Ratio; TNM, Tumor, Node, Metastasis; cut-off and all the above cut-offs were determined using ROC curves.

In our study, expressions of CEA and CA242 in patients with anastomotic leakage did not significantly differ from those without, contrasting with findings by Zhao et al., who reported elevated levels in patients with leakage [23]. This discrepancy may be due to our study's small sample size. Nonetheless, both studies observed a decrease in PNI in patients with leakage, suggesting that PNI - a measure of nutritional status and systemic resistance - might be a more stable and reliable indicator of risk for postoperative complications, including anastomotic leakage. Additionally, Su et al. found a decrease in postoperative LYM in patients with anastomotic leakage in esophageal cancer [24], whereas our study did not observe significant differences in LYM levels between groups. These variations could stem from differences in sample sizes, patient demographics, disease stages, severity, and differences in postoperative management and treatment protocols.

We developed two predictive models using logistic regression to evaluate the effectiveness of indicator-based approaches in forecasting anastomotic leakage after gastric cancer surgery. Both models, RISK1 and RISK2, demonstrated areas under the curve (AUC) exceeding 0.9, affirming their high clinical relevance. Notably, ALB was a common variable in both models, emphasizing its significance as a biomarker. ALB, a principal blood protein, is crucial for assessing nutritional status [25] and is particularly important following gastric cancer surgery where patients are vulnerable to malnutrition, thereby highlighting that a decline in ALB levels is a critical indicator [26]. Additionally, ALB serves as an indirect measure of inflammation; during inflammatory states, such as post-surgery, ALB synthesis may decrease, reflecting both compromised nutritional status and the inflammatory response [27]. This is supported by findings from Liu et al., who identified ALB as an independent risk factor for anastomotic leakage after laparoscopic intersphincteric resection for low rectal cancer [28]. Furthermore, Telem et al. reported that preoperative albumin levels below 3.5 g/dL are associated with an increased risk of anastomotic fistula following colorectal surgery [29].

Our study revealed that while the RISK scores in the anastomotic leak group were higher than those in the non-leak group for both models, there was no statistically significant difference

Table 4. Analysis of risk factors for anastomotic leakage with clinical data and laboratory indicators

Maker	β	Standard error	Vardø (city in Finnmark, Norway)	*P*-value	OR value	95% CI	
						Lower limit	Limit
ALB	-2.003	0.801	6.249	0.012	0.135	0.028	0.649
CRP	1.408	1.039	1.836	0.175	4.089	0.533	31.360
PNI	-1.448	0.862	2.825	0.093	0.235	0.043	1.272
CAR	3.145	0.711	19.543	<0.001	23.216	5.758	93.610
Surgical time	1.499	0.609	6.066	0.014	4.479	1.358	14.769
Intraoperative Bleeding	1.734	0.680	6.506	0.011	5.661	1.494	21.452
TNM staging	0.558	0.352	2.510	0.113	1.747	0.876	3.482

Note: ALB, Albumin; LYM, Lymphocyte; CRP, C-reactive protein; PNI, Prognostic Nutritional Index; CAR, C-reactive protein/Albumin Ratio; TNM, Tumor, Node, Metastasis.

Table 5. Analysis of risk factors for anastomotic leakage by laboratory indicators

Maker	β	Standard error	Vardø (city in Finnmark, Norway)	*P*-value	OR value	95% CI	
						Lower limit	Limit
ALB	-1.968	0.707	7.750	0.005	0.140	0.035	0.558
CRP	2.707	0.570	22.554	<0.001	14.992	4.904	45.826
PNI	-2.073	0.853	5.903	0.015	0.126	0.024	0.670
CAR	0.996	1.034	0.929	0.335	2.709	0.357	20.539

Note: ALB, Albumin; LYM, Lymphocyte; CRP, C-reactive protein; PNI, Prognostic Nutritional Index; CAR, C-reactive protein/Albumin Ratio.

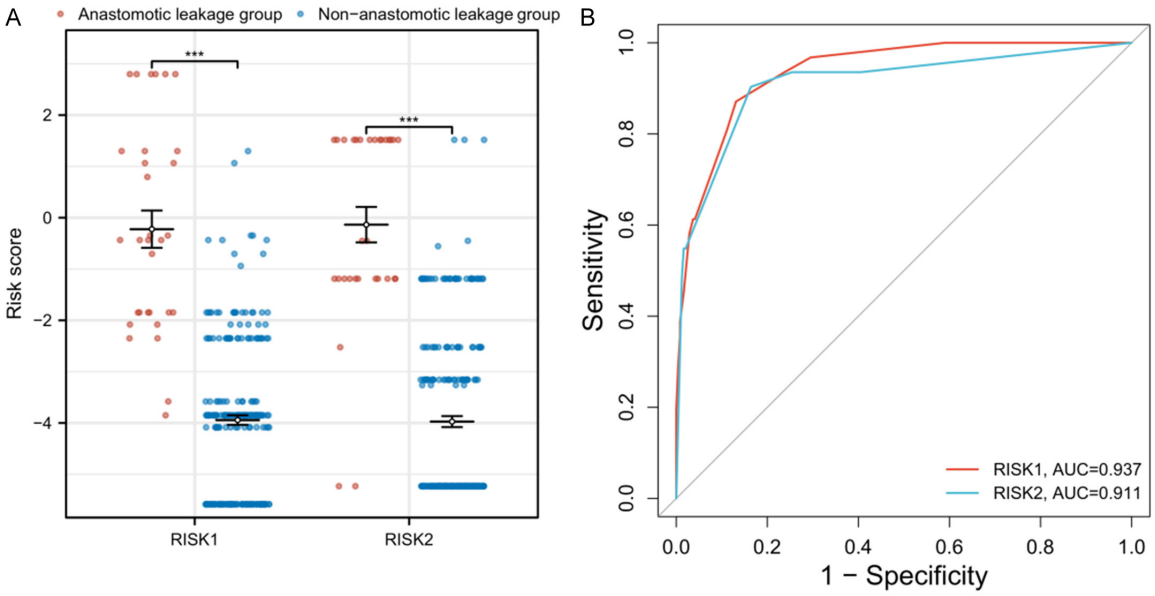

Figure 2. Comparison of the predictive efficacy of the two models. A. Comparison of the scores of patients with and without anastomotic leakage in the two models. B. ROC curves of the two models in predicting patients with anastomotic leakage. Note: RISK1 is the ROC curve of clinical data combined with laboratory indicators, and RISK2 is the ROC curve of laboratory indicators-subjects' ROC. RISK1, a combined clinical-laboratory index; RISK2, a separate laboratory index; ROC, receiver operating characteristic.

in their AUCs, indicating that both models are equally effective. RISK2, which solely relies on laboratory indicators, is particularly valuable in resource-limited settings due to its simplicity

Table 6. ROC curve parameters

Maker	The area under the curve	95% CI	Cut-off value	(Level of) sensitivity	Specificity	Accuracy	Jordon index (math.)
RISK1	0.937	0.900-0.975	-2.2165	86.89%	87.10%	86.91%	73.98%
RISK2	0.911	0.849-0.973	-1.857	83.61%	90.32%	84.36%	73.93%

Note: RISK1, a combined clinical-laboratory index; RISK2, a separate laboratory index; ROC, receiver operating characteristic.

and efficiency, enabling rapid risk assessment and minimizing subjective interpretation through objective laboratory data. The potential for automation of RISK2 allows for real-time risk alerts that can be integrated into electronic health record systems, facilitating immediate clinical decision-making and long-term patient monitoring and management.

Despite its strengths, this study has some limitations. The relatively small sample size might affect the generalizability of the results and the stability of statistical significance. Also, as a retrospective analysis, there may have been selection and information biases. Additionally, being a single-center study may limit the broad applicability of the findings. Future studies should aim for a larger, multicenter, prospective design with external validation to enhance the accuracy and reliability of the results.

In summary, this study underscores the crucial role of ALB in predicting the risk of anastomotic leakage after gastric cancer surgery and provides an effective clinical risk assessment tool, highlighting the importance of utilizing laboratory indicators in postoperative management.

Disclosure of conflict of interest

None.

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References

[1] Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA and Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin 2018; 68: 394-424.

[2] Zong L, Abe M, Seto Y and Ji J. The challenge of screening for early gastric cancer in China. Lancet 2016; 388: 2606.

[3] Joshi SS and Badgwell BD. Current treatment and recent progress in gastric cancer. CA Cancer J Clin 2021; 71: 264-279.

[4] Ajani JA, D'Amico TA, Bentrem DJ, Chao J, Cooke D, Corvera C, Das P, Enzinger PC, Enzler T, Fanta P, Farjah F, Gerdes H, Gibson MK, Hochwald S, Hofstetter WL, Ilson DH, Keswani RN, Kim S, Kleinberg LR, Klempner SJ, Lacy J, Ly QP, Matkowskyj KA, McNamara M, Mulcahy MF, Outlaw D, Park H, Perry KA, Pimiento J, Poultsides GA, Reznik S, Roses RE, Strong VE, Su S, Wang HL, Wiesner G, Willett CG, Yakoub D, Yoon H, McMillian N and Pluchino LA. Gastric cancer, version 2.2022, NCCN clinical practice guidelines in oncology. J Natl Compr Canc Netw 2022; 20: 167-192.

[5] Tsou CC, Lo SS, Fang WL, Wu CW, Chen JH, Hsieh MC and Shen KH. Risk factors and management of anastomotic leakage after radical gastrectomy for gastric cancer. Hepatogastroenterology 2011; 58: 218-223.

[6] Seicean RI, Puscasu D, Gheorghiu A, Pojoga C, Seicean A and Dindelegan G. Anastomotic leakage after gastrectomy for gastric cancer. J Gastrointestin Liver Dis 2023; 32: 526-535.

[7] Maejima K, Taniai N and Yoshida H. Risk factors for esophagojejunal anastomotic leakage in gastric cancer patients after total gastrectomy. J Nippon Med Sch 2023; 90: 64-68.

[8] Makuuchi R, Irino T, Tanizawa Y, Bando E, Kawamura T and Terashima M. Esophagojejunal anastomotic leakage following gastrectomy for gastric cancer. Surg Today 2019; 49: 187-196.

[9] Xing J, Liu M, Qi X, Yu J, Fan Y, Xu K, Gao P, Tan F, Yao Z, Zhang N, Yang H, Zhang C, Cui M and Su X. Risk factors for esophagojejunal anastomotic leakage after curative total gastrectomy combined with D2 lymph node dissection for gastric cancer. J Int Med Res 2021; 49: 3000605211000883.

[10] Kim YI, Lee JY, Khalayleh H, Kim CG, Yoon HM, Kim SJ, Yang H, Ryu KW, Choi IJ and Kim YW. Efficacy of endoscopic management for anastomotic leakage after gastrectomy in patients with gastric cancer. Surg Endosc 2022; 36: 2896-2905.

[11] Hoek VT, Sparreboom CL, Wolthuis AM, Menon AG, Kleinrensink GJ, D'Hoore A, Komen N and Lange JF. C-reactive protein (CRP) trajectory as a predictor of anastomotic leakage after rectal cancer resection: a multicentre cohort study. Colorectal Dis 2022; 24: 220-227.

[12] Ri M, Tzortzakakis A, Sotirova I, Tsekrekos A, Klevebro F, Lindblad M, Nilsson M and Rouvelas I. CRP as an early indicator for anastomotic leakage after esophagectomy for cancer: a single tertiary gastro-esophageal center study. Langenbecks Arch Surg 2023; 408: 436.

[13] Yang CK, Huang KT, Qin W, Wu QY, Huang XL, Peng K, Lao Q, Ye XP, Zhu GZ, Li TM and Peng T. Prognostic value of geriatric nutritional risk index and prognostic nutritional index in hepatocellular carcinoma. Clin Nutr ESPEN 2024; 59: 355-364.

[14] Zhang H, Shi J, Xie H, Liu X, Ruan G, Lin S, Ge Y, Liu C, Chen Y, Zheng X, Song M, Yang M, Zhang X and Shi HP. Superiority of CRP-albumin-lymphocyte index as a prognostic biomarker for patients with gastric cancer. Nutrition 2023; 116: 112191.

[15] Nakazawa N, Sohda M, Tateno K, Watanabe T, Kimura A, Kogure N, Hosaka H, Naganuma A, Sekiguchi M, Saito K, Ogata K, Sano A, Sakai M, Ogawa H, Shirabe K and Saeki H. Albumin-derived neutrophil-to-lymphocyte ratio score as a marker of nivolumab treatment sensitivity in gastric cancer: a multicenter study. In Vivo 2023; 37: 818-824.

[16] Schietroma M, Romano L, Schiavi D, Pessia B, Mattei A, Fiasca F, Carlei F and Giuliani A. Systemic inflammation response index (SIRI) as predictor of anastomotic leakage after total gastrectomy for gastric cancer. Surg Oncol 2022; 43: 101791.

[17] Zhang M, Ding C, Xu L, Ou B, Feng S, Wang G, Wang W, Liang Y, Chen Y, Zhou Z and Qiu H. Comparison of a tumor-ratio-metastasis staging system and the 8th AJCC TNM staging system for gastric cancer. Front Oncol 2021; 11: 595421.

[18] Feng RM, Zong YN, Cao SM and Xu RH. Current cancer situation in China: good or bad news from the 2018 Global Cancer Statistics? Cancer Commun (Lond) 2019; 39: 22.

[19] Shinohara H, Kurahashi Y and Ishida Y. Lymph node dissection for gastric cancer -D2 dissection as a recommended procedure and its rationale. Nihon Shokakibyo Gakkai Zasshi 2023; 120: 482-491.

[20] Shi J, Wu Z, Wu X, Shan F, Zhang Y, Ying X, Li Z and Ji J. Early diagnosis of anastomotic leakage after gastric cancer surgery via analysis of inflammatory factors in abdominal drainage. Ann Surg Oncol 2022; 29: 1230-1241.

[21] Zhang X and Jing J. Effect of peripheral blood lymphocytes on prognosis of multiple cancers. Cancer Control 2023; 30: 10732748231202921.

[22] Liu CJ, Li HY, Gao Y, Xie GY, Chi JH, Li GL, Zeng SQ, Xiong XM, Liu JH, Shi LL, Li X, Cheng XD, Song K, Ma D, Guo AY and Gao QL. Platelet RNA signature independently predicts ovarian cancer prognosis by deep learning neural network model. Protein Cell 2023; 14: 618-622.

[23] Zhao T, Li L, Wang Y, Xie W and Liu Q. Prognostic nutritional index combined with carcinoembryonic antigen and carbohydrate antigen 242 for early prediction of anastomotic leakage after radical gastrectomy for gastric cancer. Am J Transl Res 2023; 15: 4668-4677.

[24] Su P, Huang C, Lv H, Zhang Z and Tian Z. Prediction model using risk factors associated with anastomotic leakage after minimally invasive esophagectomy. Pak J Med Sci 2023; 39: 1345-1349.

[25] Wang YJ, Liu XH, Mei LY, Li KK, Jiang YG and Guo W. Do alterations in plasma albumin and prealbumin after minimally invasive esophagectomy for squamous cell carcinoma influence the incidence of cervical anastomotic leak? Surg Endosc 2016; 30: 3943-3949.

[26] Paliogiannis P, Deidda S, Maslyankov S, Paycheva T, Farag A, Mashhour A, Misiakos E, Papakonstantinou D, Mik M, Losinska J, Scognamillo F, Sanna F, Feo CF. Porcu A, Xidas A, Zinellu A, Restivo A and Zorcolo L. C reactive protein to albumin ratio (CAR) as predictor of anastomotic leakage in colorectal surgery. Surg Oncol 2021; 38: 101621.

[27] Hu K, Tan K, Shang Q, Li C, Zhang Z, Huang B, Zhao S, Li F, Zhang A, Li C, Liu B and Tong W. Relative decline in serum albumin help to predict anastomotic leakage for female patients following sphincter-preserving rectal surgery. BMC Surg 2023; 23: 38.

[28] Liu JG, Chen HK, Wang X and Tang JQ. Analysis of risk factors of anastomotic leakage after laparoscopic intersphincteric resection for low rectal cancer and construction of a nomogram prediction model. Zhonghua Wai Ke Za Zhi 2021; 59: 332-337.

[29] Telem DA, Chin EH, Nguyen SQ and Divino CM. Risk factors for anastomotic leak following colorectal surgery: a case-control study. Arch Surg 2010; 145: 371-376; discussion 376.