

Usefulness of the preoperative Prognostic Immune and Nutritional Index as a prognostic predictor for patients with gastric cancer

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Abstract. The Prognostic Immune and Nutritional Index (PINI), integrating albumin and monocyte counts, has emerged as a potential prognostic biomarker in gastrointestinal cancer. The present study aimed to evaluate its predictive value in patients with gastric cancer (GC) undergoing radical gastrectomy. A retrospective cohort study of 82 patients with GC treated at a single institute between January 2016 and December 2019 was conducted. PINI was calculated as $[\text{albumin (g/dl)} \times 0.9] - [\text{monocytes (mm}^3\text{)} \times 0.0007]$. Receiver operating characteristic analysis determined the optimal cutoff (3.075), and patients were stratified into low-PINI (≤ 3.075 ; n=33) and high-PINI (> 3.075 ; n=49) groups. Primary outcomes were 5-year recurrence-free survival (RFS) rate and overall survival (OS) rate. The high-PINI group demonstrated significantly higher 5-year RFS (79.6 vs. 51.5%; $P < 0.001$) and OS (85.7 vs. 51.5%; $P < 0.001$) rates compared with the low-PINI group. Multivariate analysis identified PINI ≥ 3.075 as an independent protective factor for both RFS [hazard ratio (HR), 0.59; 95% confidence interval (CI), 0.38-0.85; $P = 0.022$] and OS (HR, 0.45; 95% CI, 0.25-0.72; $P = 0.012$). Low-PINI patients exhibited more advanced disease characteristics, including higher rates of anemia (39.4 vs. 17.3%; $P = 0.020$), hypoproteinemia (15.2 vs. 0.0%; $P = 0.005$), advanced T stage (75.8 vs. 36.5%; $P = 0.002$), nodal metastasis (63.6 vs. 44.9%; $P = 0.002$) and stage II-III tumors (87.9 vs. 44.9%; $P < 0.001$). In conclusion, preoperative PINI serves as a robust, independent prognostic indicator in GC, effectively stratifying patients by survival outcomes and tumor aggressiveness. The clinical implementation of PINI could enhance risk assessment and guide personalized treatment strategies. Further multicenter studies are warranted to validate these findings.

Introduction

Gastric cancer (GC) is the fifth most common malignant tumor and the fifth leading cause of cancer-related deaths worldwide; in 2022, it accounted for ~968,350 new cases and 659,853 deaths globally (1). Despite advancements in targeted therapies, neoadjuvant chemotherapy and minimally invasive surgical techniques, the 5-year overall survival (OS) rate for patients with GC remains suboptimal (2). Although the eighth edition of the American Joint Committee on Cancer (AJCC) Tumor-Node-Metastasis (TNM) staging system (3) serves as the gold standard for prognostic assessment, its predictive accuracy is limited by its inability to account for key biological features such as immune microenvironment heterogeneity, metabolic dysregulation and systemic inflammatory responses (2). This limitation underscores the need for novel prognostic biomarkers that integrate multidimensional biological parameters.

In recent years, composite inflammatory-nutritional indices derived from peripheral blood components have emerged as promising prognostic tools in GC research. The Systemic Immune-Inflammation Index (calculated as $\text{platelets} \times \text{neutrophils/lymphocytes}$) ($10^9/\text{l}$) and the Prognostic Nutritional Index (calculated as $\text{albumin (g/l)} + 5 \times [\text{lymphocytes (} 10^9/\text{l)}]$) have been independently associated with postoperative recurrence risk and OS in patients with GC (4,5). However, whether single-dimensional biomarkers adequately capture the complexity of tumor-host interactions remains debatable. Addressing this question, Jung *et al* (6) innovatively proposed the Prognostic Immune and Nutritional Index (PINI), calculated as follows: $[\text{albumin (g/dl)} \times 0.9] - [\text{monocytes (mm}^3\text{)} \times 0.0007]$. This is a multidimensional model integrating nutritional status (albumin) and innate immune response (monocytes) (6). Mechanistically, hypoalbuminemia reflects not only nutritional depletion but also systemic inflammation driven by IL-6 (7), while tumor-associated monocytes secrete VEGF-A and MMP-9 to promote angiogenesis and extracellular matrix remodeling, facilitating micrometastasis (8). Notably, Xie *et al* (9) recently validated the prognostic utility of PINI in colorectal cancer, suggesting its potential applicability across tumor types.

To date, the prognostic role of PINI in GC following curative resection remains unexplored. The present single-center retrospective cohort study aimed to systematically evaluate the association between PINI and recurrence-free survival (RFS),

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as well as OS, in patients with GC, assessing its prognostic value in those undergoing radical gastrectomy. PINI may serve as a critical risk stratification tool to identify patients with high-risk GC, enabling personalized treatment strategies and optimized clinical decision-making to improve long-term outcomes.

Patients and methods

Patients. The present retrospective study analyzed clinicopathological data and laboratory hematological parameters (measured within 1 week preoperatively) from patients with GC who underwent radical gastrectomy at the Department of Gastrointestinal Surgery, The First People's Hospital of Jingdezhen (Jingdezhen, China) between January 2016 and December 2019. Clinical and preoperative (1 week prior) laboratory data were collected from a maintained patient database. The inclusion criteria were as follows: i) Primary GC with histological confirmation; ii) no previous radiation or neoadjuvant chemotherapy prior to surgery; and iii) radical GC resection. The exclusion criteria were as follows: i) Patients with additional malignancies; ii) patients with granulocytopenia or other hematological disorders; iii) a history of severe infection or an immunocompromised status within the last month; and iv) a lack of crucial baseline data and missing follow-up information.

Treatment and follow-up. The disease staging established by the Japanese Gastric Cancer Association was determined with reference to the TNM classification system (5th edition) (10). Postoperative complications occurring within 30 days were graded according to the Clavien-Dindo classification system (11), with grade III or higher complications being recorded. Following Japanese GC treatment guidelines (12), patients with stage II or III GC received adjuvant chemotherapy when deemed clinically appropriate based on their overall health status. Postoperative surveillance included contrast-enhanced computed tomography scans performed at minimum every 6 months and blood tests conducted every 3 months. Patients were followed regularly through outpatient visits or telephone interviews every 3 months starting from postoperative day 1 until reaching the study endpoint, defined as either patient death or December 31, 2024, whichever occurred first. For outcome assessment, RFS was calculated as the time from surgery to GC recurrence, last follow-up or death, while OS was defined as the time from surgery to death from any cause or last follow-up for surviving patients.

Determination of PINI. The PINI was calculated using the following formula: [albumin (g/dl) x 0.9] - [monocytes (mm³) x 0.0007], with measurements taken preoperatively (5).

Statistical analysis. Statistical analyses were performed using SPSS software (v25.0; IBM Corp.). The predictive performance of PINI for patient outcomes was evaluated through receiver operating characteristic (ROC) curve analysis, with the area under the curve (AUC) calculated to determine the optimal cutoff value using the Youden index. Based on this cutoff, patients were stratified into high-PINI and low-PINI groups for subsequent comparative analyses of clinicopathological

characteristics. Continuous variables with normal distribution are expressed as the mean $\pm$ standard deviation and compared using independent samples t-tests, while non-normally distributed continuous variables are presented as median (Q1-Q3) and were analyzed using the Mann-Whitney U test. Categorical variables are reported as n (%) and compared using either the χ^2 test or Fisher's exact test. $P < 0.05$ was considered to indicate a statistically significant difference. Univariate and multivariate Cox proportional hazards regression models were employed to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for RFS and OS. Variables demonstrating statistical significance ($P < 0.05$) in univariate analysis were included in the multivariate model. Survival probabilities for RFS and OS were estimated using the Kaplan-Meier method, with between-group differences assessed by log-rank tests.

Ethical approval. The present study received ethical approval from the Institutional Review Board of Jingdezhen First People's Hospital (approval no. jdzyykt202425) and was conducted in full compliance with the ethical principles outlined in the Declaration of Helsinki. The requirement for informed consent was waived by the ethics committee as this retrospective study utilized anonymized clinical data without any identifiable patient information.

Results

ROC analysis and survival outcomes stratified by PINI. ROC curve analysis identified an optimal PINI cutoff value of 3.075 (AUC, 0.712), demonstrating moderate predictive accuracy with 71.2% sensitivity and 69.6% specificity (Fig. 1). A total of 82 patients (aged 39-85 years) were divided into the low-PINI group (n=33; 40.2%) and the high-PINI group (n=49; 59.8%). Figs. 2 and 3 present the Kaplan-Meier analysis of RFS and OS stratified by PINI values. In Fig. 2, the 5-year RFS rate was significantly higher in the high-PINI group (PINI ≥ 3.075) at 79.6% compared with 51.5% in the low-PINI group (PINI < 3.075) (log-rank $P < 0.001$). Similarly, in Fig. 3, a higher 5-year OS rate was demonstrated in the high-PINI group (85.7%) compared with that in the low-PINI group (51.5%) (log-rank $P < 0.001$). These findings consistently indicate that elevated PINI levels are strongly associated with improved long-term survival outcomes, underscoring its potential as a significant prognostic biomarker in GC.

COX regression analysis of 5-year RFS in patients with GC after radical surgery. Table I presents the univariate and multivariate Cox regression analyses of factors associated with RFS in patients with GC. Univariate Cox regression analysis identified several significant prognostic factors for patients with GC, including surgical method (open vs. laparoscopic: HR, 0.33; 95% CI, 0.11-0.96; $P = 0.042$), anemia (yes vs. no: HR, 3.16; 95% CI, 1.46-6.85; $P = 0.004$), transfusion requirement (yes vs. no: HR, 3.04; 95% CI, 1.37-6.74; $P = 0.006$), intraoperative blood loss (≥ 150 ml, yes vs. no: HR, 2.28; 95% CI, 1.05-4.94; $P = 0.036$), operative time ≥ 210 min (yes vs. no: HR, 9.47; 95% CI, 2.84-31.63; $P < 0.001$), tumor size ≥ 3.5 cm (yes vs. no: HR, 3.46; 95% CI, 1.50-7.98; $P = 0.004$), T stage (T0-1 vs. T2-4: HR, 0.18; 95% CI, 0.06-0.51; $P = 0.001$), nodal involvement (N0 vs.

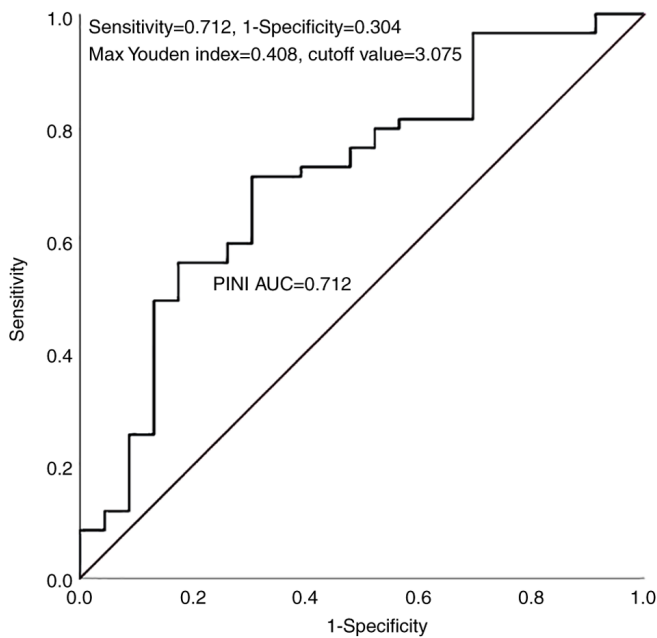


Figure 1. Receiver operating characteristic curve for the PINI. AUC, area under the curve; PINI, Prognostic Immune and Nutritional Index.

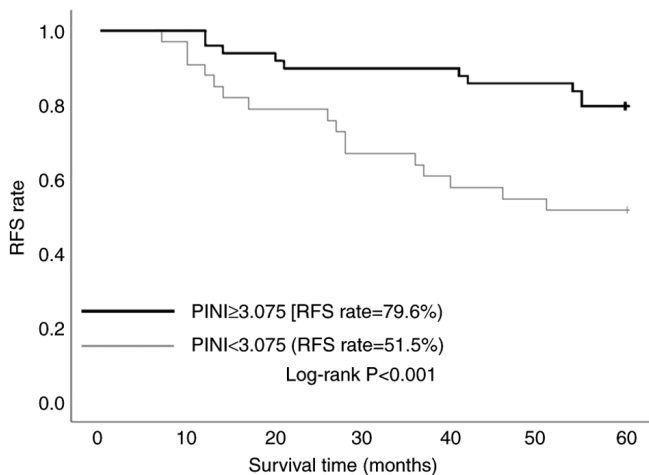


Figure 2. RFS in patients with gastric cancer in the PINI-high and PINI-low groups. RFS, recurrence-free survival; PINI, Prognostic Immune and Nutritional Index.

N1-3: HR, 0.14; 95% CI, 0.03-0.59; $P=0.008$), pathological stage (I vs. II-III: HR, 0.17; 95% CI, 0.05-0.57; $P=0.004$) and PINI ≥ 3.075 (yes vs. no: HR, 0.30; 95% CI, 0.13-0.68; $P=0.004$). In multivariate analysis, operative time ≥ 210 min (yes vs. no: HR, 5.38; 95% CI, 1.32-21.93; $P=0.019$) and pathological stage (I vs. II-III: HR, 0.63; 95% CI, 0.25-0.88; $P=0.037$) remained independent predictors, while PINI ≥ 3.075 retained significance as a protective factor (yes vs. no: HR, 0.59; 95% CI, 0.38-0.85; $P=0.022$).

COX regression analysis of 5-year OS in GC patients after radical surgery. Table II demonstrates the prognostic factors influencing OS in patients with GC through comprehensive Cox regression analyses. Univariate Cox regression analysis revealed several significant predictors of OS in patients

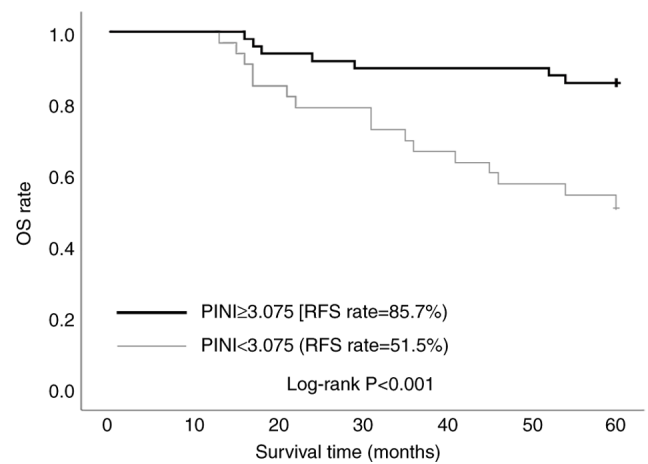


Figure 3. OS of patients with GC in the PINI-high and PINI-low groups. OS, overall survival; PINI, Prognostic Immune and Nutritional Index.

with GC, including anemia (yes vs. no: HR, 2.89; 95% CI, 1.25-6.71; $P=0.013$), hypertension (yes vs. no: HR, 3.62; 95% CI, 1.07-12.28; $P=0.039$), hypoproteinemia (yes vs. no: HR, 3.62; 95% CI, 1.07-12.28; $P=0.039$), transfusion requirement (yes vs. no: HR, 3.13; 95% CI, 1.34-7.34; $P=0.009$), operative time ≥ 210 min (yes vs. no: HR, 11.56; 95% CI, 2.70-49.54; $P<0.001$), tumor size ≥ 3.5 cm (yes vs. no: HR, 3.95; 95% CI, 1.54-10.10; $P=0.004$), T stage (T0-1 vs. T2-4: HR, 0.23; 95% CI, 0.08-0.67; $P=0.007$), N stage (N0 vs. N1-3: HR, 0.08; 95% CI, 0.01-0.62; $P=0.015$), pathological stage (I vs. II-III: HR, 0.21; 95% CI, 0.06-0.72; $P=0.013$) and PINI ≥ 3.075 (yes vs. no: HR, 0.29; 95% CI, 0.12-0.69; $P=0.005$). Multivariate analysis confirmed that operative time ≥ 210 min (yes vs. no: HR, 7.12; 95% CI, 1.41-35.96; $P=0.017$) and pathological stage (I vs. II-III: HR, 0.32; 95% CI, 0.08-0.89; $P=0.045$) maintained their status as independent prognostic indicators. Importantly, a PINI score ≥ 3.075 continued to demonstrate significant protective effects (yes vs. no: HR, 0.45; 95% CI, 0.25-0.72; $P=0.012$) in the final model.

Patient characteristics. This comparative analysis of 82 patients with GC stratified by PINI levels (low-PINI: <3.075 , $n=33$; high-PINI: ≥ 3.075 , $n=49$) revealed significant differences in clinical and pathological characteristics (Table III). The low-PINI group demonstrated substantially higher rates of adverse features, including anemia (39.4 vs. 16.3%; $P=0.020$), hypoproteinemia (15.2 vs. 0.0%; $P=0.005$), pyloric stenosis (12.1 vs. 0%; $P=0.013$), transfusion requirements (33.3 vs. 12.2%; $P=0.022$) and postoperative complications (36.4 vs. 16.3%; $P=0.039$). Pathologically, patients in the low-PINI group showed more advanced disease with higher T2-4 stage (75.8 vs. 36.5%; $P=0.002$), nodal involvement (63.6 vs. 44.9%; $P=0.002$) and stage II-III tumors (87.9 vs. 44.9%; $P<0.001$). Notably, the median PINI values differed significantly between groups (2.77 vs. 3.39; $P<0.001$). These findings collectively demonstrate that low PINI status is strongly associated with worse nutritional parameters, more advanced tumor characteristics and poorer surgical outcomes, suggesting its potential as a comprehensive marker integrating both inflammatory and nutritional status for risk stratification in patients with GC.

Table I. Univariate and multivariate analysis for recurrence-free survival in patients with gastric cancer.

Variables	Univariate analysis		Multivariate analysis	
	HR (95% CI)	P-value	HR (95% CI)	P-value
Age (<65 vs. ≥65 years)	0.58 (0.27-1.25)	0.168		
Sex (male vs. female)	1.38 (0.58-3.28)	0.466		
Tumor location (upper-middle part vs. lower part)	1.79 (0.83-3.86)	0.672		
Surgical procedure (TG vs. no TG)	0.63 (0.07-5.43)	0.676		
Surgical method (open vs. laparoscopic)	0.33 (0.11-0.96)	0.042	0.73 (0.38-4.15)	0.263
Anastomotic methods (BI + BII vs. R-Y)	1.25 (0.44-3.58)	0.672		
Anemia (yes vs. no)	3.16 (1.46-6.85)	0.004	2.67 (0.89-8.03)	0.080
Hypertension (yes vs. no)	3.09 (0.92-10.31)	0.067		
Pulmonary disease (yes vs. no)	1.57 (0.66-3.74)	0.307		
Diabetes (yes vs. no)	1.45 (0.43-4.82)	0.547		
Cardiovascular disease (yes vs. no)	0.39 (0.05-2.88)	0.356		
Hypoproteinemia (yes vs. no)	3.09 (0.92-10.31)	0.067		
Pyloric stenosis (yes vs. no)	1.87 (0.44-7.91)	0.397		
Hospital stay ≥27 days (yes vs. no)	1.08 (0.50-2.36)	0.840		
Postoperative hospital stay ≥16 days (yes vs. no)	2.19 (0.98-4.92)	0.057		
Transfusion (yes vs. no)	3.04 (1.37-6.74)	0.006	0.61 (0.18-2.02)	0.416
Postoperative complications (yes vs. no)	1.55 (0.67-3.57)	0.281		
Adjuvant chemotherapy (yes vs. no)	1.69 (0.68-4.22)	0.257		
Operative time ≥210 min (yes vs. no)	9.47 (2.84-31.63)	<0.001	5.38 (1.32-21.93)	0.019
Intraoperative blood loss ≥150 ml (yes vs. no)	2.28 (1.05-4.94)	0.036	1.17 (0.48-2.84)	0.735
Tumor size ≥3.5 cm (yes vs. no)	3.46 (1.50-7.98)	0.004	1.69 (0.66-4.31)	0.271
T stage (T0-1 vs. T2-4)	0.18 (0.06-0.51)	0.001	0.45 (0.12-1.75)	0.292
N stage (N0 vs. N1-3)	0.14 (0.03-0.59)	0.008	0.70 (0.13-3.89)	0.686
pStage (I vs. II-III)	0.17 (0.05-0.57)	0.004	0.63 (0.25-0.88)	0.037
Histopathology (well-moderately vs. poorly)	0.70 (0.31-1.57)	0.390		
PINI ≥3.075 (yes vs. no)	0.30 (0.13-0.68)	0.004	0.59 (0.38-0.85)	0.022

HR, hazard ratio; CI, confidence interval; TG, total gastrectomy; BI, Billroth I; BII, Billroth II; R-Y, Roux-en-Y; T, tumor; N, regional lymph node; pStage, pathological stage; PINI, Prognostic Immune and Nutritional Index.

Discussion

Hematological biomarkers offer distinct advantages, including accessibility, cost-effectiveness and reliable accuracy, with high patient acceptance and compliance. The PINI, as a representative hematological biomarker, has garnered increasing attention for its role in tumorigenesis, metastasis and antitumor immunity (13). The present retrospective analysis of patients with GC demonstrated that elevated PINI levels were significantly associated with improved RFS and OS rates. To the best of our knowledge, this represents the first study in China to systematically integrate PINI with clinicopathological parameters in patients with GC, not only providing novel insights for personalized treatment but also validating the prognostic value of PINI in this population. These findings establish PINI as both an independent prognostic factor and a potential biomarker for guiding nutritional support and optimizing therapeutic strategies. The optimal PINI cutoff value identified in the present study (3.075) warrants discussion in the context of existing literature. Jung *et al* (6) initially proposed a cutoff value of 3.0 for risk stratification in patients with colorectal cancer

undergoing radical resection, while Xie *et al* (9) subsequently recommended 2.85 based on Chinese colorectal cancer cohorts. The observed variations in optimal thresholds may stem from several factors, including methodological differences in statistical approaches, inherent tumor heterogeneity across cancer types and demographic variations among study populations. These factors collectively contribute to the observed fluctuations in establishing prognostic PINI thresholds.

The clinical relevance of PINI stems from its integration of albumin and monocyte counts, reflecting both inflammatory and nutritional status. Inflammatory cytokines disrupt protein metabolism by altering the balance between synthesis and degradation. Albumin, a classical nutritional marker, is regulated by proinflammatory cytokines, including IL-1, IL-6 and TNF- α (14,15). Patients with GC frequently develop malnutrition (prevalence up to 80%) due to increased protein catabolism and reduced intake, leading to elevated mortality, prolonged hospitalization, postoperative complications and treatment toxicity (16,17). Systemic inflammation plays a pivotal role in tumor progression and metastasis (18-21), while monocytes, as key inflammatory markers, facilitate tumor progression

Table II. Univariate and multivariate analysis for overall survival in patients with gastric cancer.

Variables	Univariate analysis		Multivariate analysis	
	HR (95% CI)	P-value	HR (95% CI)	P-value
Age (<65 vs. ≥65 years)	0.56 (0.250-1.23)	0.158		
Sex (male vs. female)	1.09 (0.45-2.68)	0.845		
Tumor location (upper-middle part vs. lower part)	1.76 (0.826-3.863)	0.574		
Surgical procedure (TG vs. no TG)	0.58 (0.07-5.00)	0.623		
Surgical method (open vs. laparoscopic)	0.41 (0.14-1.22)	0.108		
Anastomotic methods (BI + BII vs. R-Y)	1.04 (0.32-3.42)	0.944		
Anemia (yes vs. no)	2.89 (1.25-6.71)	0.013	2.18 (0.60-7.92)	0.234
Hypertension (yes vs. no)	3.62 (1.07-12.28)	0.039	1.15 (0.25-5.31)	0.856
Pulmonary disease (yes vs. no)	1.27 (0.47-3.44)	0.641		
Diabetes (yes vs. no)	1.78 (0.53-6.02)	0.353		
Cardiovascular disease (yes vs. no)	1.06 (0.250-4.53)	0.936		
Hypoproteinemia (yes vs. no)	3.62 (1.07-12.28)	0.039	1.15 (0.25-5.31)	0.856
Pyloric stenosis (yes vs. no)	2.16 (0.50-9.25)	0.301		
Hospital stay ≥27 days (yes vs. no)	1.03 (0.45-2.35)	0.942		
Postoperative hospital stay ≥16 days (yes vs. no)	2.15 (0.91-5.08)	0.081		
Transfusion (yes vs. no)	3.13 (1.34-7.34)	0.009	0.61 (0.16-2.29)	0.465
Postoperative complications (yes vs. no)	1.94 (0.81-4.62)	0.136		
Adjuvant chemotherapy (yes vs. no)	1.70 (0.63-4.60)	0.300		
Operative time ≥210 min (yes vs. no)	11.56 (2.70-49.54)	<0.001	7.12 (1.41-35.96)	0.017
Intraoperative blood loss ≥150 ml (yes vs. no)	2.17 (0.94-5.03)	0.070		
Tumor size ≥3.5 cm (yes vs. no)	3.95 (1.54-10.10)	0.004	1.75 (0.60-5.09)	0.306
T factor (T0-1 vs. T2-4)	0.23 (0.08-0.67)	0.007	0.62 (0.14-2.72)	0.529
N factor (N0 vs. N1-3)	0.08 (0.01-0.62)	0.015	0.47 (0.05-4.45)	0.510
pStage (I vs. II-III)	0.21 (0.06-0.72)	0.013	0.32 (0.08-0.89)	0.045
Histopathology (well-moderately vs. poorly)	0.66 (0.28-1.58)	0.213		
PINI ≥3.075 (yes vs. no)	0.29 (0.12-0.69)	0.005	0.45 (0.25-0.72)	0.012

HR, hazard ratio; CI, confidence interval; TG, total gastrectomy; BI, Billroth I; BII, Billroth II; R-Y, Roux-en-Y; T, tumor; N, regional lymph node; pStage, pathological stage; PINI, Prognostic Immune and Nutritional Index.

by creating an immunosuppressive microenvironment (22). Elevated monocyte counts correlate with a poor prognosis and lymph node metastasis in multiple malignancies, including Kaposi sarcoma (23), chronic lymphocytic leukemia (24), myelodysplastic neoplasms (25), pancreatic cancer (26), lung cancer (27) and solid tumors (28). The present study findings revealed that patients with $\text{PINI} \geq 3.075$ had significantly higher 5-year RFS ($P < 0.001$) and OS ($P < 0.001$) rates, with PINI emerging as an independent protective factor ($P < 0.05$) following radical gastrectomy.

Multivariate analysis confirmed pathological stage as an independent prognostic factor for both RFS and OS ($P < 0.05$). Advanced tumors create a vicious cycle where increased tumor burden exacerbates systemic catabolism, while tumor-induced inflammation further suppresses immune function, accelerating disease progression (29,30). In the present study, the low-PINI group exhibited significantly higher rates of anemia, hypoproteinemia, pyloric stenosis, transfusion requirements and postoperative complications. Notably, the median PINI values differed significantly between groups. Pathological

evaluation revealed more advanced disease in the low-PINI group, including deeper tumor invasion, greater nodal metastasis and advanced-stage tumors, suggesting that low PINI reflects exacerbated inflammation and malnutrition, which predict adverse outcomes. These findings support the potential clinical value of nutritional and immunomodulatory interventions for patients with low PINI. Prolonged operative time (≥ 210 min) was identified as an independent prognostic factor for both RFS and OS in patients with GC following surgery. This association may be attributed to several potential factors, including a larger tumor size with advanced staging, tumor invasion into the surrounding tissues leading to unclear surgical margins, technical difficulties in tissue dissection, intraoperative bleeding requiring hemostasis or conversion to open surgery in some cases.

The present study has several limitations that warrant consideration. First, the single-center retrospective design and relatively limited sample size may introduce selection bias, highlighting the need for future multicenter studies with larger cohorts to validate the findings. Second, the proposed PINI

Table III. Baseline characteristics according to the PINI in 82 patients with gastric cancer.

Variables	Total	Low-PINI	High-PINI	P-value
Patients, n (%)	82 (100.0)	33 (40.2)	49 (59.8)	
Mean age $\pm$ SD, years	61.60 $\pm$ 10.03	63.88 $\pm$ 10.53	60.06 $\pm$ 9.49	0.091
Sex, n (%)				0.949
Male	55 (67.1)	22 (66.7)	33 (67.3)	
Female	27 (32.9)	11 (33.3)	16 (32.7)	
Tumor location, n (%)				0.693
Upper part	6 (7.3)	2 (6.1)	4 (8.2)	
Middle part	26 (31.7)	12 (36.4)	14 (28.6)	
Lower part	50 (61.0)	19 (57.6)	31 (63.3)	
Surgical procedure, n (%)				0.247
Total gastrectomy	14 (17.1)	4 (12.1)	10 (20.4)	
No total gastrectomy	68 (82.9)	29 (87.9)	39 (79.6)	
Surgical method, n (%)				0.236
Open	56 (21.7)	25 (75.8)	31 (63.3)	
Laparoscopic surgery	26 (68.3)	8 (24.2)	18 (36.7)	
Anastomotic methods, n (%)				0.214
BI	21 (25.6)	11 (33.3)	10 (20.4)	
BII	43 (52.4)	16 (48.5)	27 (55.1)	
R-Y	18 (22.0)	6 (18.2)	12 (24.5)	
Anemia, n (%)				0.020
Yes	21 (25.6)	13 (39.4)	8 (16.3)	
No	61 (74.4)	20 (60.6)	41 (83.7)	
Hypertension, n (%)				0.606
Yes	25 (30.5)	9 (27.3)	16 (32.7)	
No	57 (69.5)	24 (72.7)	33 (67.3)	
Pulmonary disease, n (%)				0.233
Yes	17 (20.7)	9 (27.3)	8 (16.3)	
No	65 (79.3)	24 (72.7)	41 (83.7)	
Diabetes, n (%)				0.179
Yes	8 (9.8)	5 (15.2)	3 (6.1)	
No	74 (90.2)	28 (84.8)	46 (93.9)	
Cardiovascular disease, n (%)				0.146
Yes	7 (8.5)	1 (3.0)	6 (12.2)	
No	75 (91.5)	32 (97.0)	43 (87.8)	
Hypoproteinemia, n (%)				0.005
Yes	5 (6.1)	5 (15.2)	0 (0.0)	
No	77 (93.9)	28 (84.8)	49 (100.0)	
Pyloric stenosis, n (%)				0.013
Yes	4 (4.9)	4 (12.1)	0 (0.0)	
No	78 (95.1)	29 (87.9)	49 (100.0)	
Hospital stay, days	26 (16-80)	27 (17-62)	26 (16-80)	0.429
Postoperative hospital stay, days	16 (11-61)	16 (12-46)	17 (11-61)	0.239
Transfusion, n (%)				0.022
Yes	17 (20.7)	11 (33.3)	6 (12.2)	
No	65 (79.3)	22 (66.7)	43 (87.8)	
Postoperative complications, n (%)				0.039
Yes	20 (24.4)	12 (36.4)	8 (16.3)	
No	62 (75.6)	21 (63.6)	41 (83.7)	
Adjuvant chemotherapy, n (%)				0.096
Yes	26 (31.7)	7 (21.2)	19 (38.8)	
No	56 (68.3)	26 (78.8)	30 (61.2)	

Table III. Continued.

Variables	Total	Low-PINI	High-PINI	P-value
Operative time ≥ 210 min, n (%)				0.098
Yes	43 (52.4)	21 (63.6)	22 (44.9)	
No	39 (47.6)	12 (36.4)	27 (55.1)	
Intraoperative blood loss ≥ 150 ml, n (%)				0.055
Yes	25 (30.5)	14 (42.4)	11 (22.4)	
No	57 (69.5)	19 (57.6)	38 (77.6)	
Tumor size ≥ 3.5 cm, n (%)				0.162
Yes	37 (45.1)	18 (54.5)	19 (38.8)	
No	45 (54.9)	15 (45.5)	30 (61.2)	
T factor, n (%)				0.002
T0-1	44 (53.6)	8 (24.2)	36 (73.5)	
T2-4	38 (46.4)	25 (75.8)	13 (26.5)	
N factor, n (%)				0.002
N0	39 (47.6)	12 (36.4)	27 (55.1)	
N1-3	43 (52.4)	21 (63.6)	22 (44.9)	
pStage, n (%)				<0.001
I	31 (37.8)	4 (12.1)	27 (55.1)	
II-III	51 (62.2)	29 (87.9)	22 (44.9)	
Histopathology, n (%)				0.711
Well-moderately differentiated	59 (72.0)	23 (69.7)	36 (73.5)	
Poorly differentiated	23 (28.0)	10 (30.3)	13 (26.5)	
Median PINI (Q1, Q3)	3.20 (2.83, 3.44)	2.77 (2.51, 2.90)	3.39 (3.27, 3.57)	<0.001

PINI, Prognostic Immune and Nutritional Index HR, hazard ratio; CI, confidence interval; BI, Billroth I; BII, Billroth II; R-Y, Roux-en-Y; T, tumor; N, regional lymph node; pStage, pathological stage; SD, standard deviation.

cutoff value was derived from a single institutional dataset, necessitating external validation through collaborative multi-center research to confirm its generalizability across diverse populations. Finally, the exclusive reliance on single-timepoint PINI measurements precluded assessment of dynamic changes in this parameter over time, suggesting that future prospective studies incorporating serial measurements would provide more comprehensive insights into its clinical utility.

In conclusion, the present study establishes PINI as a simple yet powerful prognostic tool for patients with GC undergoing radical resection. The study findings demonstrate the following: i) PINI ≥ 3.075 independently predicts superior long-term survival outcomes; ii) the index effectively stratifies patients by surgical risk and tumor aggressiveness; and iii) it provides complementary value to conventional TNM staging. The biological plausibility of PINI, reflecting both systemic inflammation and nutritional status, strengthens its clinical relevance. While requiring external validation, these results suggest PINI could be readily incorporated into routine preoperative assessment to identify high-risk patients who may benefit from nutritional optimization or intensified surveillance. Future research should focus on prospective multicenter validation and investigate whether PINI-guided interventions can improve clinical outcomes. The present study advances

the field by providing clinicians with a practical, cost-effective tool to enhance personalized decision-making in gastric cancer management.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

JL and SZ were responsible for the study conceptualization and methodology. JL and LY were responsible for validation, investigation and resources. Data curation, which consisted of

data collection, data cleaning, data organization, data analysis preparation, and quality assurance, was performed by JL, LY, XH, TH and MC. JL and LY confirm the authenticity of all the raw data. JL wrote the original draft, and JL and SZ reviewed and edited the manuscript. Study visualization was performed by JL and LY. SZ supervised the study, while project administration was performed by JL, LY, XH, TH and MC. All authors have read and approved the final version of the manuscript.

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee at The First People's Hospital of Jingdezhen (Jingdezhen, China; approval no. jdzzykt202425). The requirement for informed consent was waived due to the retrospective nature of the study and data anonymization.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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