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Original Article

Combined impact of prognostic nutritional index, fibrinogen-to-albumin ratio, and neutrophil-to-lymphocyte ratio on surgical outcomes and prognosis in hepatocellular carcinoma

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Abstract: This study evaluated the predictive value of the prognostic nutritional index (PNI), fibrinogen-to-albumin ratio (FAR), and neutrophil-to-lymphocyte ratio (NLR) for overall survival in hepatocellular carcinoma (HCC) patients. A total of 283 HCC cases from Hunan Provincial People's Hospital were included in the analysis, with 45 additional patients as external validation. The relationship between these indices and patient prognosis was further evaluated using the Kaplan-Meier method and Cox regression analysis. Receiver operating characteristic (ROC) curve analysis was performed to assess the predictive performance of these indices for overall survival (OS) and to determine the optimal cutoff values. ROC curve analysis revealed that the area under the curve (AUC) for PNI, FAR, and NLR was 0.723, 0.857, and 0.872, respectively. Multivariate analysis identified hepatitis history, intraoperative blood transfusion, FAR, NLR, and PNI as independent prognostic factors (all $P<0.05$). The resulting prediction model demonstrated strong performance in both the training (C-index =0.917) and external validation (C-index =0.853) cohorts, with AUCs of 0.889 and 0.931 for 6-month and 1-year prediction in the validation set, respectively. These findings suggest that preoperative levels of peripheral blood PNI, FAR, and NLR are closely associated with the surgical prognosis of HCC patients. The prognostic prediction model developed based on these indices exhibits good predictive efficacy.

Keywords: Hepatocellular carcinoma, prognostic nutritional index, fibrinogen-to-albumin ratio, neutrophil-to-lymphocyte ratio, overall survival

Introduction

Liver cancer ranks among the leading malignancies worldwide in both incidence and mortality. According to data from the National Cancer Center of China, there were 367,700 new cases of primary liver cancer and 316,500 deaths in 2022, making it the fourth most common cancer by incidence and second leading cause of cancer-related mortality [1, 2]. Primary liver cancer mainly includes hepatocellular carcinoma (HCC), intrahepatic cholangiocarcinoma (ICC), and combined hepatocellular-cholangiocarcinoma (cHCC-CCA), with HCC accounting for 75%-85% of cases [3, 4]. While surgical resection remains the primary curative treatment for early-stage HCC [5, 6], long-term outcomes remain unsatisfactory, with the 5-year recurrence rate as high as 70% [7]. This high recurrence rate underscores the critical need for reliable prognostic markers to guide treatment decisions and improve patient outcomes. Inflammation and nutritional status play crucial roles in cancer progression and patient survival. In recent years, several blood-based biomarkers have emerged as promising prognostic indicators in cancer patients [8, 9].

The Prognostic Nutritional Index (PNI) is a comprehensive biomarker that integrates nutritional status and immune function. Calculated using the formula PNI = 10 × serum albumin (g/dL) + 0.005 × total lymphocyte count (per mm^3), it provides a nuanced assessment of a patient's

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physiological condition [10, 11]. Albumin, a key protein synthesized by the liver, reflects nutritional status and inflammatory response, while lymphocyte count serves as an indicator of immune system competence. Low PNI values have consistently been associated with poor nutritional status, compromised immune function, and increased surgical complications across various malignancies [10-12]. In HCC patients, low PNI has been significantly associated with increased recurrence risk, particularly in elderly populations [12].

The Neutrophil-to-Lymphocyte Ratio (NLR) emerges as a robust inflammatory marker reflecting the complex interaction between systemic inflammation and cancer progression. Calculated by dividing the absolute neutrophil count by the absolute lymphocyte count, NLR represents the balance between pro-inflammatory (neutrophils) and anti-tumor immune responses (lymphocytes) [9]. Elevated NLR indicates a systemic inflammatory state characterized by neutrophil proliferation and lymphocyte suppression, which can promote tumor invasion, metastasis, and resistance to therapeutic interventions.

The Fibrinogen-to-Albumin Ratio (FAR) represents an innovative composite marker that integrates inflammatory, nutritional, and coagulation parameters. Calculated by dividing serum fibrinogen levels by serum albumin concentration, FAR captures the complex interplay between systemic inflammation, nutritional status, and coagulative processes. Elevated fibrinogen is associated with chronic inflammation, enhanced tumor angiogenesis, and prothrombotic states, while low albumin levels indicate malnutrition and poor physiological reserve. In HCC, FAR has shown potential as an independent predictor of tumor progression, metastasis, and patient survival [13].

Inflammation and nutritional status play crucial roles in cancer progression and patient survival. In recent years, several blood-based biomarkers have emerged as promising prognostic indicators in cancer patients [8, 9]. While PNI reflects nutritional and immune competence, NLR represents systemic inflammatory response, and FAR combines inflammatory and nutritional markers, these indices offer complementary insights into a patient's physiological condition. While these individual markers PNI, FAR, and NLR have shown promise in predicting cancer outcomes, their combined prognostic value in HCC remains underexplored. The multifaceted nature of these markers suggests that their integrated assessment may provide more comprehensive and nuanced prognostic information compared to their individual evaluation.

As these indices reflect different yet complementary aspects of a patient's nutritional and inflammatory status, evaluating them together may yield more comprehensive prognostic insights. Therefore, this study aims to evaluate the combined prognostic value of PNI, FAR, and NLR in predicting the surgical outcomes and prognosis of HCC patients.

Materials and methods

Patient characteristics

This retrospective study involved HCC cases that treated at Hunan Provincial People's Hospital from January 2020 to January 2024, including 283 cases as the modeling dataset for establishing the predictive model, and another 80 cases as an external validation set to assess the performance of the predictive model. Inclusion criteria: 1) age ≥18 years; 2) pathologically confirmed primary HCC [14]; 3) underwent open or laparoscopic surgical resection, minimally invasive/local treatment; 4) complete follow-up data. Exclusion criteria: 1) presence of other malignant tumors; 2) severe cardiac, pulmonary, or renal dysfunction; 3) acute infection or exacerbation of autoimmune disease within one month prior to surgery; 4) incomplete preoperative data. This study was approved by the Medical Ethics Committee of Hunan Provincial People's Hospital (LY-2024-393).

Data collection

Demographic characteristics, including age, sex, and body mass index (BMI), along with recorded medical history and family cancer history, were collected. Tumor characteristics include size and number of tumors.

Laboratory test data encompassed complete blood count (white blood cell count, neutrophil count, lymphocyte count, platelet count), liver function indicators [alanine aminotransferase

(ALT), aspartate aminotransferase (AST), total bilirubin (STB), gamma-glutamyl transferase (GGT), albumin (Alb)], coagulation function indicators including prothrombin time (PT), fibrinogen (Fib), and tumor markers (alpha-fetoprotein, AFP). The PNI, FAR, and NLR were calculated using the formulas: PNI = serum albumin (g/L) + 5 × total lymphocyte count (×10^^{9}/L), FAR = plasma fibrinogen (g/L)/serum albumin (g/L), and NLR = neutrophil count/lymphocyte count [15-17]. PNI≥50 indicates normal nutritional status and PNI<50 indicates malnutrition [16]. Surgical-related information included surgical method, duration, intraoperative blood loss, and whether blood transfusions were administered along with the transfusion volume. Postoperative complications include postoperative hepatic insufficiency, bile leakage, postoperative bleeding, infection, and ascites.

By reviewing medical records and outpatient follow-up documentation, relevant follow-up information was collected, including survival status, recurrence, and metastasis. The follow-up period started from the time of liver cancer diagnosis, with the primary prognostic indicator being overall survival (OS), to death from any cause or the last follow-up. The last follow-up date was January 31, 2024.

Statistical analysis

Statistical analyses were conducted using SPSS 26.0 and R 4.4 software. Continuous variables were expressed as mean ± standard deviation or median (interquartile range), while categorical variables were reported as frequency (percentage). Receiver operating characteristic (ROC) curve analysis was employed to evaluate the predictive ability of PNI, FAR, and NLR for OS and to determine optimal cutoff values. Chi-square tests or Fisher's exact tests were used to compare clinical characteristics across different PNI, FAR, and NLR level groups. Kaplan-Meier methods were applied to generate survival curves, and Log-rank tests were utilized to compare survival differences between groups. Independent risk factors affecting OS were screened using univariate and multivariate Cox proportional hazards regression models. A nomogram prediction model was constructed based on the results of Cox regression findings, and model performance was evaluated using C-index, ROC curves, and calibration curves. Internal validation was assessed using a 10-fold cross-validation method, and external validation was performed on an external dataset. A *p*-value of <0.05 was considered statistically significant.

Results

Clinical characteristics of patients in the modeling and validation sets

The average age of the 283 HCC patients was 58 years (range: 50.5-65.0), and the average BMI was 23.4 kg/m^2 (range: 21.5-25.6) (**Table 1**). Of these patients, 80.6% had a history of hepatitis, 49.1% had cirrhosis, and 2.5% had a family history of tumors. Laparoscopic liver resection was performed in 30.0% of cases, while 68.6% underwent open liver resection, and 1.4% received minimally invasive/local treatment. Intraoperative blood transfusions were required for 10.6% of patients, and 42.0% experienced surgical complications. Recurrence occurred in 12.0% of patients, and 25.0% of patients died.

In the validation set (n=45), the mean age was 60 years (55.5-65.5 years), and the mean BMI was 23.0 kg/m^2 (23.0-24.0 kg/m^2). There were no significant differences in age, sex, BMI, history of hepatitis, cirrhosis, family history of cancer, surgery time, surgical complications, length of stay and recurrence between the two groups (P>0.05). However, significant differences were noted in surgical method, intraoperative blood transfusion and survival status (P<0.05).

Univariate and multivariate cox regression analysis of prognostic factors

Univariate Cox regression analysis was performed to identify potential prognostic factors for OS in HCC patients (**Figure 1A**). The analysis revealed several significant factors: high NLR (HR=12.25, 95% CI: 5.31-28.28, P<0.001), high FAR (HR=6.79, 95% CI: 3.37-13.67, P< 0.001) and intraoperative blood transfusion (HR=3.67, 95% CI: 2.12-6.37, P<0.001) were associated with poor survival. Conversely, high PNI (HR=0.33, 95% CI: 0.19-0.55, P<0.001) and history of hepatitis (HR=0.51, 95% CI: 0.3-0.86, P=0.012) showed protective effects. However, gender (P=0.156), age (P=0.423), cirrhosis (P=0.241), and family history of cancer (P=0.175) were not significant factors.

Table 1. Clinical characteristics of patients in both modeling and validation groups

Characteristic		Modeling set (n=283)	Validation set (n=45)	Z/χ^2	P
Age (year), M [Q1-Q3]		58.0 (50.5-65.0)	60.0 (55.5-65.50)	-1.253	0.210
Gender	Male	233 (82.3)	33 (73.3)	2.051	0.152
	Female	50 (17.7)	12 (26.7)		
BMI (kg/m^2), M [Q1-Q3]		23.4 (21.5-25.6)	23.0 (23.0-24.0)	-0.560	0.576
History of Hepatitis	No	55 (19.4)	13 (18.9)	2.112	0.146
	Yes	228 (80.6)	32 (71.1)		
Cirrhosis	No	144 (50.9)	23 (51.1)	0.001	0.977
	Yes	139 (49.1)	22 (48.9)		
Family History of Cancer	No	276 (97.5)	79 (98.8)		
	Yes	7 (2.5)	1 (1.2)		
Surgical method	Laparoscopic hepatectomy	85 (30.0)	2 (4.4)	29.744	<0.001
	Open hepatectomy	194 (68.6)	34 (75.6)		
	Minimally invasive/topical treatment	4 (1.4)	9 (20.0)		
Surgery time (h), M [Q1-Q3]		5.0 (3.8-6.5)	5.2 (4.2-5.9)	-0.135	0.893
Intraoperative Blood Transfusion	No	253 (89.4)	45 (100)	-	0.021
	Yes	30 (10.6)	0 (0)		
Surgical complications	No	164 (58.0)	30 (66.7)	1.221	0.269
	Yes	119 (42.0)	15 (33.3)		
Length of stay (day), M [Q1-Q3]		17.0 (13.0-20.0)	17.0 (12.5-20.5)	-0.009	0.993
Recrudesce	No	249 (88.0)	43 (95.6)	2.277	0.131
	Yes	34 (12.0)	2 (4.4)		
Status	Survival	212 (75.00)	40 (88.9)	4.261	0.039
	Death	71 (25.00)	5 (11.1)		

BMI: body mass index.

Subsequently, variables with statistical significance in the univariate analysis were included in the multivariate Cox regression model (**Figure 1B**). The results identified five independent prognostic factors: intraoperative blood transfusion (HR=3.34, 95% CI: 1.89-5.88, P< 0.001), high NLR (HR=11.63, 95% CI: 4.83-27.99, P<0.001), and high FAR (HR=4.12, 95% CI: 2.02-8.38, P<0.001) were associated with increased risk, while history of hepatitis (HR=0.48, 95% CI: 0.28-0.82, P=0.008) and high PNI (HR=0.52, 95% CI: 0.31-0.90, P= 0.018) emerged as protective factors.

Relationship between PNI, FAR, NLR, and OS in HCC patients

Survival rates and median survival times varied significantly across patients with different levels of PNI, FAR, and NLR (P<0.001, **Figure 2**). The high PNI group maintained a survival rate above 75% over a 40-month follow-up period, while the low PNI group dropped to below 50% by 20 months. The low FAR group exhibited survival rates close to 100% throughout the follow-up, whereas the high FAR group fell to 25% by 30 months. Similarly, the low NLR group also approached 100% survival, while the high NLR group decreased to 35% by 30 months. The high PNI group did not reach a median survival time, whereas the median survival times for the low PNI, high FAR, and high NLR groups were 16.6, 16.2, and 16.1 months, respectively.

Optimal cut-off for PNI, FAR, and NLR in predicting overall mortality

ROC curve analysis demonstrated that AUCs for predicting overall mortality were 0.723 for PNI, 0.857 for FAR, and 0.872 for NLR, with optimal cut-off points of 42.885, 3.095, and 0.0865, respectively (**Table 2** and **Figure 3**).

Correlation analysis of PNI, FAR, NLR with clinical characteristics

Correlation analysis revealed significant relationships between PNI, FAR, and NLR and various clinical characteristics (**Figure 4**). PNI showed an significant negative correlations

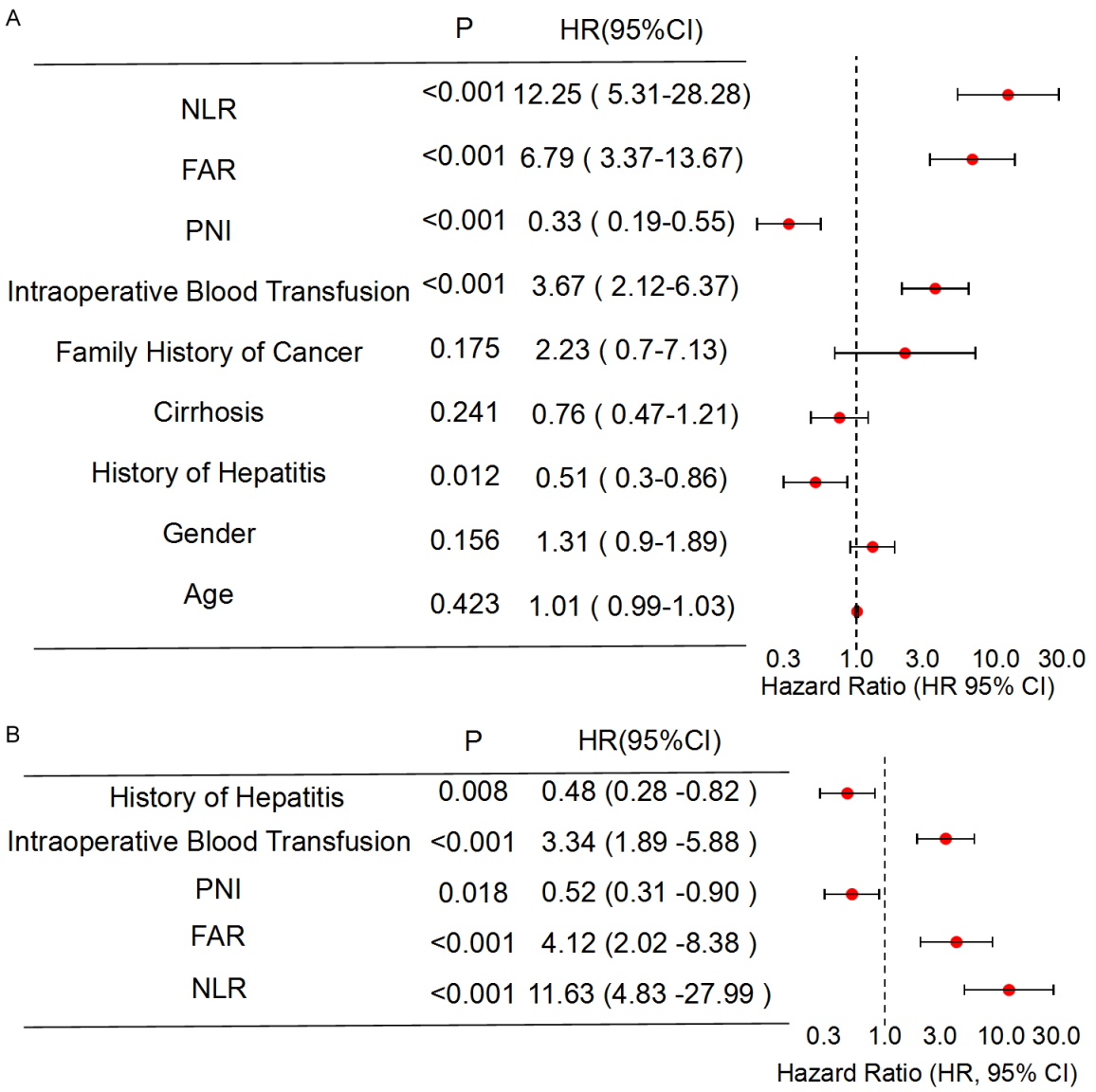

Figure 1. Univariate and multivariate cox regression analysis of prognostic factors in HCC patients. A: Univariate cox regression analysis of clinical parameters associated with overall survival. B: Multivariate cox regression analysis of independent prognostic factors for overall survival.

with age (r=-0.136) and surgical complications (r=-0.147, P<0.05), FAR showed a significant negative correlation with cirrhosis (r=-0.131, P<0.05), and NLR was positively correlated with surgery time (r=0.252, P<0.001), surgical complications (r=0.231, P<0.001), and intraoperative blood transfusion (r=0.141, P< 0.05) but negatively correlated with cirrhosis (r=-0.166, P<0.01).

Nomogram model for prognostic prediction

A nomogram model based on the Cox proportional hazards regression was constructed to predict survival probabilities at 6 months, 1 year, 1.5 years, and 2 years, incorporating multiple variables including history of hepatitis, intraoperative blood transfusion, PNI, FAR, and NLR (**Figure 5**). To validate the model's robustness, 10-fold cross-validation was employed, where the dataset was randomly partitioned into 10 subsets, with 9 subsets iteratively used as the training set and 1 subset as the testing set, to evaluate the model's stability and generalization performance under different data partitioning conditions. The average C-index of 10-fold cross-validation was 0.917, indicating

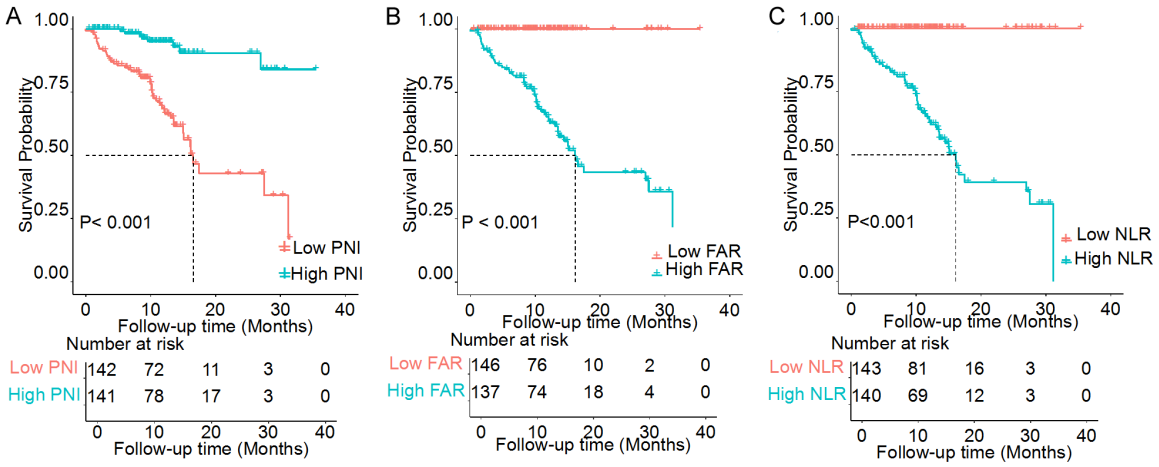

Figure 2. Survival curves of patients with different PNI (A), FAR (B), and NLR (C) levels.

Table 2. Predictive performance of PNI, FAR, and NLR for OS in HCC patients

Variables	AUC	95% CI	P	Sensitivity	Specificity	Cut-off
PNI	0.723	0.655-0.791	<0.001	0.858	0.507	42.885
NLR	0.857	0.809-0.904	<0.001	0.859	0.807	3.095
FAR	0.872	0.827-0.916	<0.001	0.817	0.797	0.0865

AUC: Area Under the Curve; PNI: Prognostic Nutritional Index; NLR: Neutrophil-to-Lymphocyte Ratio; FAR: Fibrinogen-to-Albumin Ratio; OS: Overall Survival; HCC: hepatocellular carcinoma; OS: Overall Survival; HCC: Hepatocellular Carcinoma.

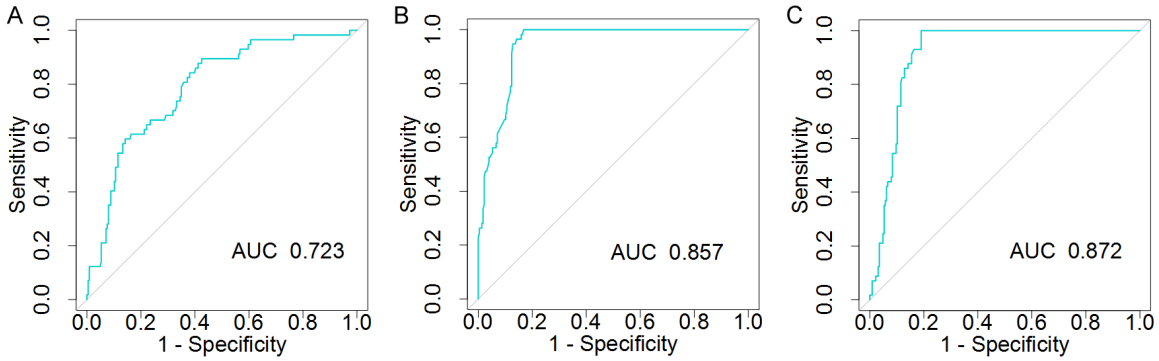

Figure 3. Receiver operating characteristic (ROC) curves for PNI (A), FAR (B), and NLR (C) in predicting mortality in HCC patients. PNI: Prognostic Nutritional Index; NLR: Neutrophil-to-Lymphocyte Ratio; FAR: Fibrinogen-to-Albumin Ratio.

high discriminative ability across the entire dataset.

Model performance is illustrated in **Figure 6**. The AUC values were 0.964 for the training set (**Figure 6A**) and 0.897 for the testing set (**Figure 6B**). Calibration curves for both the training set (**Figure 6C**) and testing set (**Figure 6D**) demonstrated good agreement between predicted probabilities and actual survival rates, suggesting that the model not only effectively discriminates between survival and mortality risks but also provides numerically accurate survival probability predictions. When assessing the predictive effects of PNI, FAR, and NLR individually in the training set, the AUC values were 0.724, 0.823, and 0.816, respectively. However, the combined AUC for all three factors improved significantly to 0.961 (**Figure 7A**). In the validation set, the individual AUC values for PNI, FAR, and NLR were 0.688, 0.675, and 0.713, respectively (**Figure 7B**).

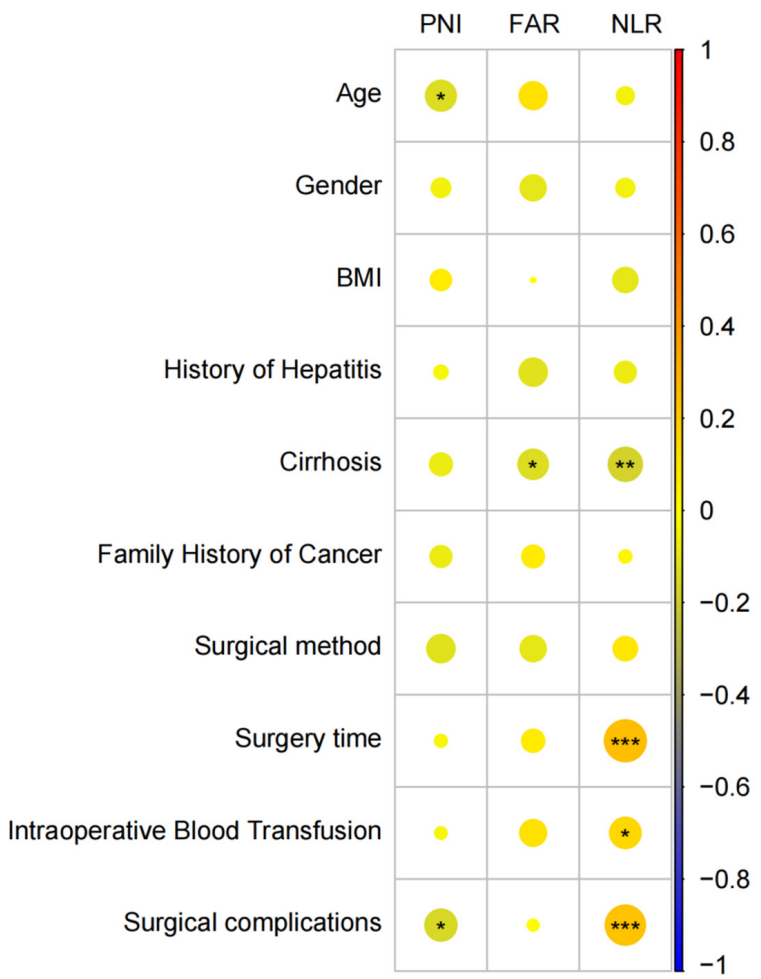

Figure 4. Relationship between preoperative PNI, FAR, NLR and clinical characteristics of HCC patients. PNI: Prognostic Nutritional Index; NLR: Neutrophil-to-Lymphocyte Ratio; FAR: Fibrinogen-to-Albumin Ratio; ***≤0.001, **≤0.01, *≤0.05.

While the combined AUC value for the three factors in the validation set decreased to 0.807, it remained higher than the individual predictions.

In the external validation dataset, the model achieved a C-index of 0.853, demonstrating its robustness on novel data. Furthermore, the AUC for 6-month and 1-year predictions were 0.889 and 0.931, respectively (**Figure 8**), indicating high accuracy in short-term survival prediction.

Discussion

This study systematically investigated the prognostic value of three inflammation-nutrition-based markers (PNI, FAR, and NLR) in HCC patients undergoing surgical resection. Our findings revealed a complex interplay between systemic inflammation, nutritional status, and cancer outcomes, supporting the critical role of these markers in risk stratification and treatment optimization. The relationship between inflammation, nutrition, and cancer progression has garnered increasing attention in recent years. HCC, in particular, develops in a unique microenvironment characterized by chronic inflammation and metabolic dysfunction, making inflammation-nutrition-based markers especially relevant. Our findings demonstrate that these markers not only reflect the patient's condition but also provide valuable insights into the underlying disease mechanisms and potential therapeutic targets.

A higher PNI reflects better nutritional status and immune function, both of which are associated with improved prognosis [18-22]. The prognostic value of PNI stems from its dual representation of nutritional status, through albumin levels, immune function, and lymphocyte count. Albumin not only serves as a nutritional marker, but also plays a vital role as antioxidant and in maintaining oncotic pressure. Meanwhile, lymphocytes are essential for orchestrating antitumor immunity. The synergistic effect of these components may explain why PNI outperforms individual parameters in prognostic prediction [23]. Malnutrition in HCC patients is particularly challenging due to the liver's central role in protein synthesis and metabolism. Our findings align with mounting evidence suggesting that preoperative nutritional optimization is crucial in HCC, compared to other malignancies. For instance, mechanistic studies have shown that malnutrition impairs liver regeneration capacity and promotes tumor progression by altering metabolic pathways and compromising im-

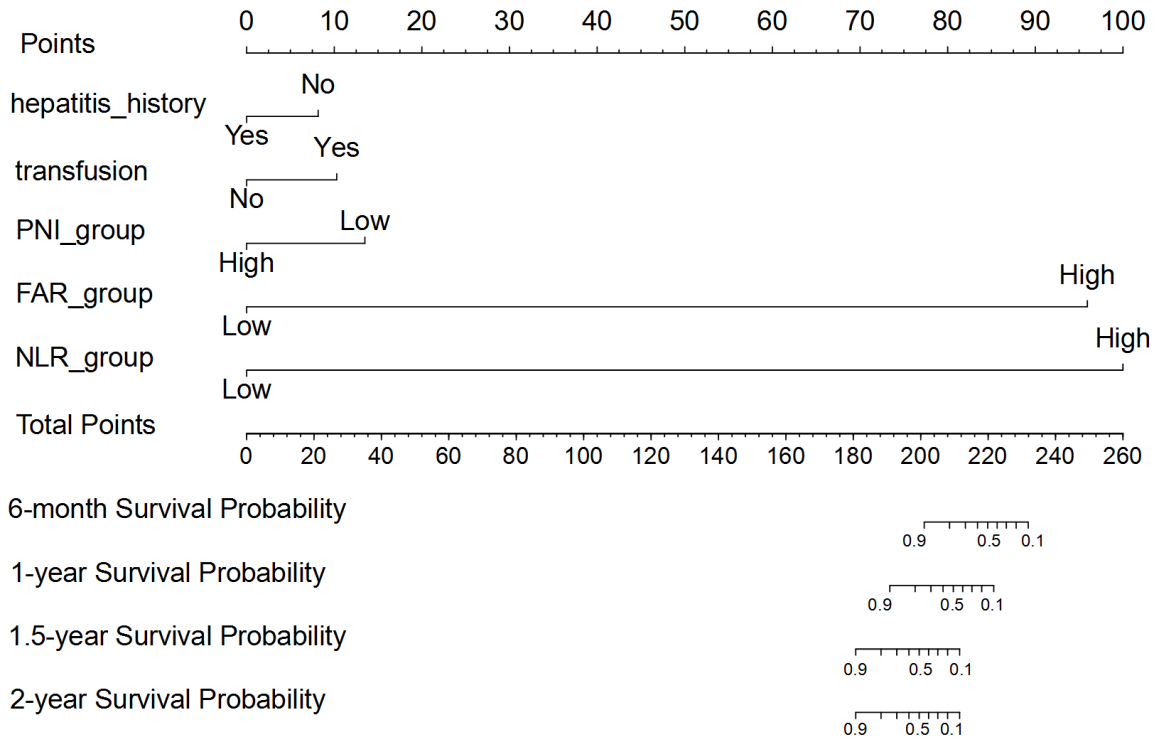

Figure 5. Nomogram based on the cox proportional hazards regression model.

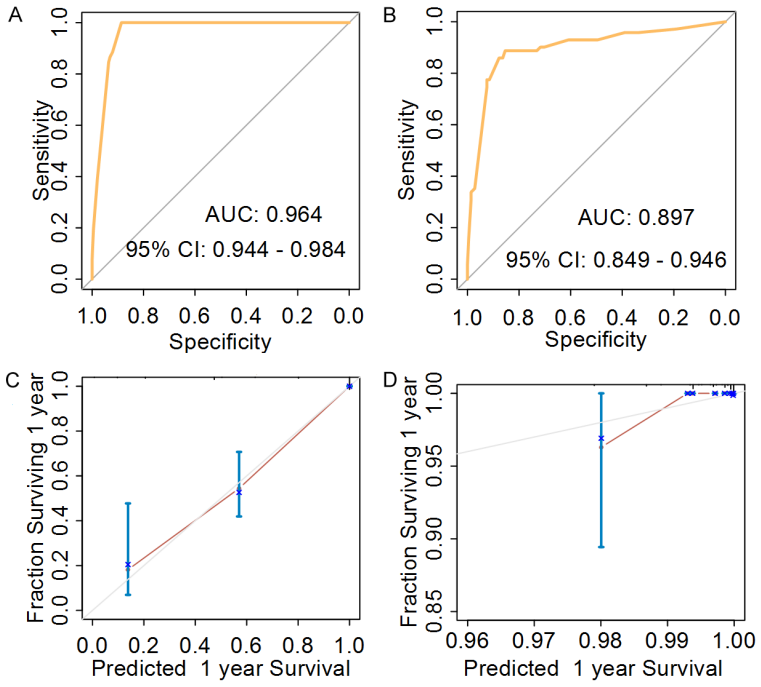

Figure 6. Performance of the predictive model. A: ROC curve for the training set. B: ROC curve for the testing set. C: Calibration curve for the training set. D: Calibration curve for the testing set. ROC: Receiver operating characteristic.

mune surveillance [24, 25]. Research by Njoku et al. [26] explored PNI's prognostic value in endometrial cancer, revealing that while PNI as a continuous variable showed no significant correlation with prognosis, it became an independent prognostic factor when using specific cutoff points (≥45). This threshold effect, which we also observed in our study, suggests that certain critical points in nutritional status can significantly impact cancer outcomes. Figuring out these thresholds could help optimize preoperative nutritional intervention strategies.

In conclusion, identifying the impact of malnutrition on postoperative outcomes and establishing clinically applicable assessment parameters could make preoperative nutritional

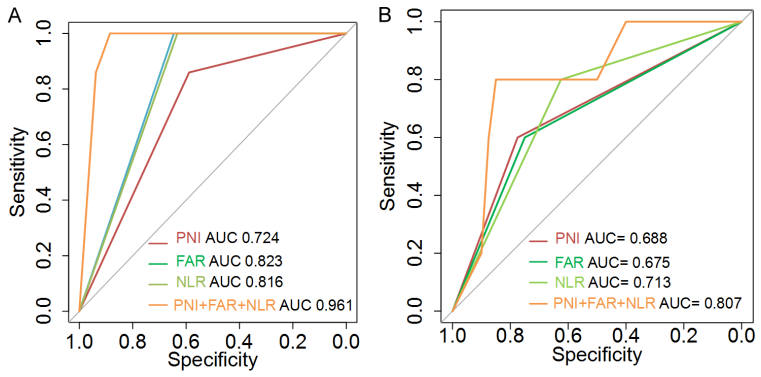

Figure 7. Predictive performance of PNI, FAR and NLR alone and joint prediction models in training set (A) and validation set (B).

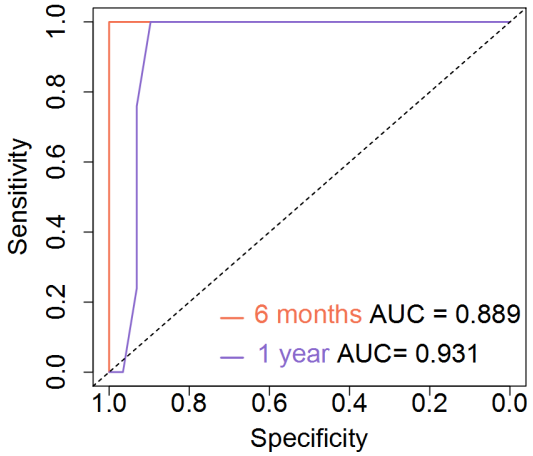

Figure 8. Time-dependent ROC curves for model validation in validation set. ROC: Receiver operating characteristic.

interventions an effective strategy for optimizing patient prognosis. However, the reliability of PNI as a candidate for selecting patients for nutritional intervention remains unclear. Therefore, future prospective studies are needed to explore the application value of nutritional interventions for patients with low PNI in the perioperative management of liver cancer.

FAR represents a novel integration of coagulation cascade activation (fibrinogen) and nutritional status (albumin), providing unique insights into the complex interactions between inflammation and cancer progression. Our finding of FAR's prognostic value in HCC is particularly noteworthy, given the liver's dual role in producing both fibrinogen and albumin. An elevated FAR may reflect not only systemic inflammation but also impaired liver function and altered protein synthesis specific to HCC. Fibrinogen, a glycoprotein synthesized by hepatocytes, is elevated during inflammatory responses and plays a key role in coagulation and inflammation [27-32]. Albumin, the most abundant protein in plasma, is primarily synthesized by the liver and serves as a marker of nutritional status while modulating inflammatory responses [33-37]. Recent molecular studies have revealed that fibrinogen promotes tumor progression through multiple mechanisms, including enhancing tumor cell adhesion and migration via interaction with various integrins, promoting angiogenesis by stabilizing growth factor signaling, and contributing to the formation of pre-metastatic niches [38-41]. These mechanisms may explain why elevated FAR correlates with poor prognosis in our cohort.

In this study, we found that patients in the low FAR group exhibited significantly higher survival rates, aligning with previous findings [42-47]. ROC curve analysis revealed the optimal FAR cutoff value for predicting mortality in liver cancer patients. Similar findings have been reported in pancreatic cancer, where a study analyzing survival data from 282 patients who underwent R0 resection found that preoperative high plasma FAR (>0.08) was significantly associated with poor prognosis [48]. Thus, FAR, as a comprehensive marker reflecting systemic inflammatory and immune responses, may provide more accurate prognostic stratification for HCC patients.

In contrast, NLR, as a marker of systemic inflammatory response, has demonstrated strong consistency and stability in predicting patient outcomes. Neutrophils can promote tumor proliferation and angiogenesis through cytokine secretion and vascular endothelial growth factor (VEGF), while lymphocytes play a crucial role in tumor immune surveillance [49-53]. Patients in the low NLR group had significantly higher survival rates. Elevated NLR not only reflects systemic inflammation but may also indicate changes in the tumor microenvironment and immune suppression [54-60]. The

strong prognostic value of NLR observed in our study may be explained by its representation of both pro-tumor (neutrophils) and anti-tumor (lymphocytes) immune responses. Recent research has revealed that tumor-associated neutrophils can promote metastasis through neutrophil extracellular traps (NETs), suppress T cell responses through myeloid-derived suppressor cell (MDSC) activity, and enhance tumor angiogenesis through matrix metalloproteinase release [61-63].

Multivariate analysis revealed that intraoperative transfusion was an independent risk factor affecting patient survival,while the presence of hepatitis history showed a protective effect. Theses finding underscores the importance of perioperative management, particularly in assessing and controlling bleeding risk. Patients without a history of hepatitis may not have undergone monitoring and early treatment for chronic HBV infection, potentially leading to delayed detection and management during the progression of liver cancer, resulting in poorer prognosis [64].

Furthermore, the integration of these three markers (PNI, FAR, and NLR) provides complementary information about the patient's inflammatory and nutritional status. While each marker has its own prognostic value, their combination may offer more comprehensive risk stratification by capturing different aspects of the complex relationship between inflammation, nutrition, and cancer progression.

Our study also has some limitations. Firstly, it is a single-center retrospective analysis, which may introduce selection bias. Secondly, the follow-up period is relatively short, preventing the assessment of these markers' impact on long-term prognosis. Future research directions could focus on the following areas: 1) conducting large-scale, multicenter prospective studies to validate our findings; 2) extending the follow-up duration to evaluate the predictive value of these markers for 5- and even 10-year survival rates; 3) integrating imaging and molecular biomarkers to develop more accurate prognostic models; and 4) exploring the molecular mechanisms underlying changes in these markers to provide a theoretical basis for targeted interventions.

In summary, this study confirms the value of PNI, FAR, and NLR in assessing the prognosis of patients undergoing liver cancer surgery, particularly highlighting the significant predictive capability of NLR. These findings offer clinicians practical tools that can help optimize patient management strategies and improve treatment outcomes.

Disclosure of conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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