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ORIGINAL RESEARCH

Analysis of Influencing Factors and Establishment of Nomogram Model for Textbook Outcome Achievement in Laparoscopic Resection of Hepatocellular Carcinoma

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Objective: To analyse the influencing factors for textbook outcome (TO) achievement in laparoscopic hepatectomy for hepatocellular carcinoma (HCC) and to construct and validate a nomogram model.

Methods: A total of 200 patients with HCC who underwent laparoscopic hepatectomy in our hospital between January 2022 and December 2024 were retrospectively analysed and divided into a TO group (n = 116) and a non-TO group (n = 84) according to the TO in liver surgery criteria. Twenty clinical parameters were collected, and after univariate analysis to screen variables, multivariate logistic regression was performed to determine independent influencing factors and establish nomograms. Model discrimination, calibration and clinical benefit were assessed using receiver operating characteristic (ROC) curves, calibration curves and decision curves.

Results: Multivariate logistic analysis showed that no malnutrition before operation (odds ratio [OR] = 0.051; 95% confidence interval [CI]: 0.014–0.179), intraoperative blood loss <225 mL (OR = 0.096; 95% CI: 0.030–0.310) and postoperative hospital stay <12.5 days (OR = 0.061; 95% CI: 0.021–0.182) were independent protective factors for TO (all $P < 0.05$). The nomogram C-index was 0.931; the area under the ROC curve was 0.983 (95% CI: 0.971–0.995), sensitivity was 0.948 and specificity was 0.929; the calibration curve fitted well with the ideal curve; and the decision curve showed that the model had a significant positive net benefit. Subgroup analysis based on resection extent (minor vs major hepatectomy) confirmed the model's robust performance, with AUCs of 0.984 and 0.976 respectively, demonstrating consistent predictive accuracy across different surgical complexities.

Conclusion: Preoperative nutritional status, intraoperative blood loss and postoperative hospital stay are independent factors for achieving TO in laparoscopic resection of HCC. The constructed nomogram has excellent predictive performance and can be used to identify high-risk patients in the early clinical stage and guide individualised intervention.

Keywords: hepatectomy, hepatocellular carcinoma, textbook outcome, influencing factors, nomogram model

Introduction

Hepatocellular carcinoma (HCC) is the third leading cause of cancer-related deaths worldwide.[1,2] Although laparoscopic liver resection has been shown to substantially reduce postoperative complications and improve survival, the short-term outcome varies greatly among different centres.[3] Traditional evaluation indicators, such as the complication rate, 90-day mortality and readmission rate, can only reflect the risk of a single dimension, and it is difficult to comprehensively evaluate the perioperative quality and overall recovery of patients.[4,5]

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Multiple studies[6–8] have shown that textbook outcome (TO) can more accurately and comprehensively assess the surgical quality and short-term prognosis of patients. In 2022, the International Hepato-Pancreato-Biliary Association (IHPBA) published the "Textbook Outcome after Liver Surgery (TOLS) Consensus", which, for the first time, defined "textbook outcome (TO)" as the following: an R0 resection margin, no intraoperative ≥grade 2 events, no grade B/C bile leak or liver failure, no 90-day major complications, no readmission and death, and no prolonged hospital stay (>75th percentile).[7]

Multiple retrospective studies have confirmed that patients with HCC achieving TO not only have significantly reduced short-term complications but also a 5-year overall survival rate, which is 15–25% higher than those not achieving TO, suggesting that TO can be used as an early surrogate endpoint for long-term survival.[8] However, existing studies suggest that the achievement rate of TO varies considerably (35–71%), and the influencing factors are not yet unified. Reported risk factors include a preoperative low albumin–bilirubin (ALBI) grade, intraoperative bleeding >300 mL, operative time >240 min, extensive hepatectomy and concomitant portal hypertension. The critical impact of preoperative nutritional status on long-term surgical outcomes in patients with HCC is becoming increasingly recognised. For instance, Ji et al demonstrated that both low prognostic nutritional index and low body mass index (BMI) values are independent predictors of reduced disease-free and overall survival after hepatectomy for HCC. The combination of these two factors can even provide greater predictive accuracy.[9] Lee et al further emphasised the detrimental effects of malnutrition on short-term outcomes through a comprehensive analysis of a US national database. Their study showed that malnourished patients undergoing hepatectomy had significantly higher in-hospital mortality, longer hospital stays, higher costs and increased risks of complications such as bleeding, infection and respiratory failure.[10] However, when focusing on the composite short-term quality metric TO, most existing TO studies are single centre with sample sizes of less than 200 cases and have not adopted the internationally unified TOLS criteria. Crucially, data on the impact of preoperative nutritional status – specifically, malnutrition diagnosed using the more comprehensive Global Leadership Initiative on Malnutrition (GLIM) criteria, which includes muscle mass assessment – on the likelihood of achieving TO remain lacking.[11]

Therefore, based on the latest TOLS definition, this study included patients undergoing laparoscopic HCC resection, systematically analysed the effects of preoperative, intraoperative and postoperative variables on TO, and constructed a visualised nomogram model, aiming to provide an evidence-based basis for precise perioperative management and lay the foundation for subsequent multicentre validation.

Materials and Methods

General Information

This study used a retrospective case–control study method to collect and analyse the clinical data of patients with HCC who underwent laparoscopic hepatectomy in the First Affiliated Hospital of Ningbo University between 2022 and 2024. The inclusion criteria were as follows: (1) patients with pathological diagnosis of HCC and undergoing laparoscopic HCC resection; (2) no other tumours; and (3) complete research data. The exclusion criteria were as follows: (1) HCC combined with severe organ dysfunction; (2) emergency admission and surgery due to ruptured liver cancer with bleeding; and (3) incomplete information. A total of 200 patients were included, consisting of 166 men and 34 women, with an average age of 62.36 ± 11.89 years. According to whether the patients achieved TO after surgery, they were divided into two groups: a TO group (n = 116) and a non-TO group (n = 84) (Figure 1).

This study was approved by the Ethics Committee of the First Affiliated Hospital of Ningbo University, with approval number 2023 Research No. 079RS-01. An informed consent form was signed by all participants in this study.

Data Collection

General Information

Patient basic information and clinical data were collected through the electronic medical record system of the First Affiliated Hospital of Ningbo University: (1) basic information included age, gender, BMI, hepatitis B history and alcohol consumption history; (2) preoperative data consisted of alpha-fetoprotein (AFP), platelet (PLT), aspartate aminotransferase (AST), alanine aminotransferase (ALT), bilirubin (TBIL) and albumin (ALB) levels; (3) intraoperative

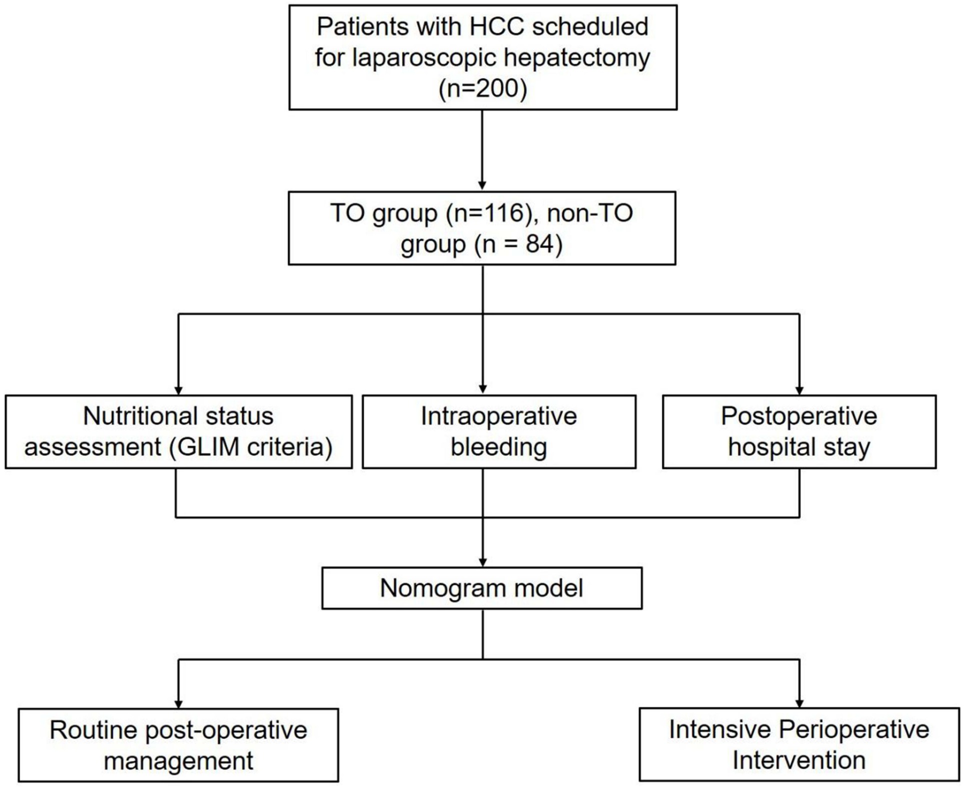

Figure 1 Flow chart.

data consisted of operation time, resection range, intraoperative blood loss and whether blood transfusion was performed; (4) pathological data included tumour diameter, tumour stage, differentiation degree and microvascular invasion.

Malnutrition Diagnosis

The GLIM criteria,[12] consisting of two steps, were used to assess patients for malnutrition. The first step is to screen for nutritional risk using the Nutritional Risk Screening 2002 (NRS2002) and to screen out patients with NRS2002 ≥ 3 points; the second step is to diagnose malnutrition in patients at nutritional risk. Malnutrition is diagnosed if at least one item each of the phenotypic criteria (non-voluntary weight loss, low BMI, decreased muscle mass) and etiologic criteria (reduced food intake or absorption >2 weeks, disease burden/inflammatory condition) are met.[13] The assessment of reduced muscle mass was performed by measuring the circumference of the calf, in accordance with the "GLIM Diagnostic Criteria for Muscle Mass Phenotype in Malnutrition: A Guide for Assessment". The circumference of the non-dominant calf was used as the assessment indicator, with a critical value of <34 cm for men and <33 cm for women. During the measurement, the patient was asked to stand with their feet shoulder-width apart, and a non-stretchable measuring tape was used to measure the circumference of the thickest part of the non-dominant calf. The measurement was performed three times consecutively, and the average value was taken as the final result.

Textbook Outcome Evaluation Criteria

Based on a literature review and in conjunction with the 2022 IHPBA latest published international expert consensus on TOLS, the evaluation criteria for this study were defined as the following: 1) an R0 resection margin; 2) no intraoperative ≥grade 2 events; 3) no postoperative grade B/C bile fistula disease; 4) no postoperative grade B/C liver failure; 5) no major postoperative complications within 90 days postoperatively; 6) no surgery-related complications leading to 90-day readmission; 7) no 90-day or in-hospital mortality; 8) no prolonged postoperative hospital stay (defined as a hospital stay greater than the 75th percentile). Intraoperative event grading was based on N.K. Francis's European Association for Endoscopic Surgeons classification system of intraoperative adverse events.[14]

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Statistical Analysis

For statistical analysis, SPSS 26.0 and MedCalc software were used. Measurement data conforming to normal distribution were analysed using the *t*-test, and those not conforming to normal distribution were analysed through the Mann–Whitney *U*-test. The results were expressed as mean ± standard deviation. Count data were analysed using the chi-square test, and the results were expressed as a frequency. Univariate analysis was performed on all data, and independent variables with $P < 0.05$ in the univariate analysis were included in the binary logistic multivariate regression analysis. A P-value <0.05 was considered statistically significant. Receiver operating characteristic (ROC) curve analysis was used to calculate the optimal cut-off values of postoperative hospital stay and intraoperative blood loss, and the above two measurement data were transformed into count data. Based on the multivariate logistic regression analysis, independent influencing factors (postoperative hospital stay, intraoperative blood loss, malnutrition assessment) were obtained, and the variables were included in the nomogram prediction model to construct a nomogram (Figure 2) for patients with HCC undergoing laparoscopic hepatectomy to achieve TO. To further investigate the impact of surgical complexity on the achievement of TO, a predefined subgroup analysis was performed based on the extent of liver resection. The classification of resection procedures followed the internationally standardized terminology of the Brisbane 2000 classification of liver anatomy and resections, which provides a consistent framework for defining the scope of hepatic surgery.[15] For the purpose of this analysis, resections were stratified into two categories: Minor resection, which included wedge resections and segmentectomies; and Major resection, which encompassed hemihepatectis, extended hemihepatectomies, and any resection of three or more segments.[16] The baseline characteristics and perioperative outcomes were

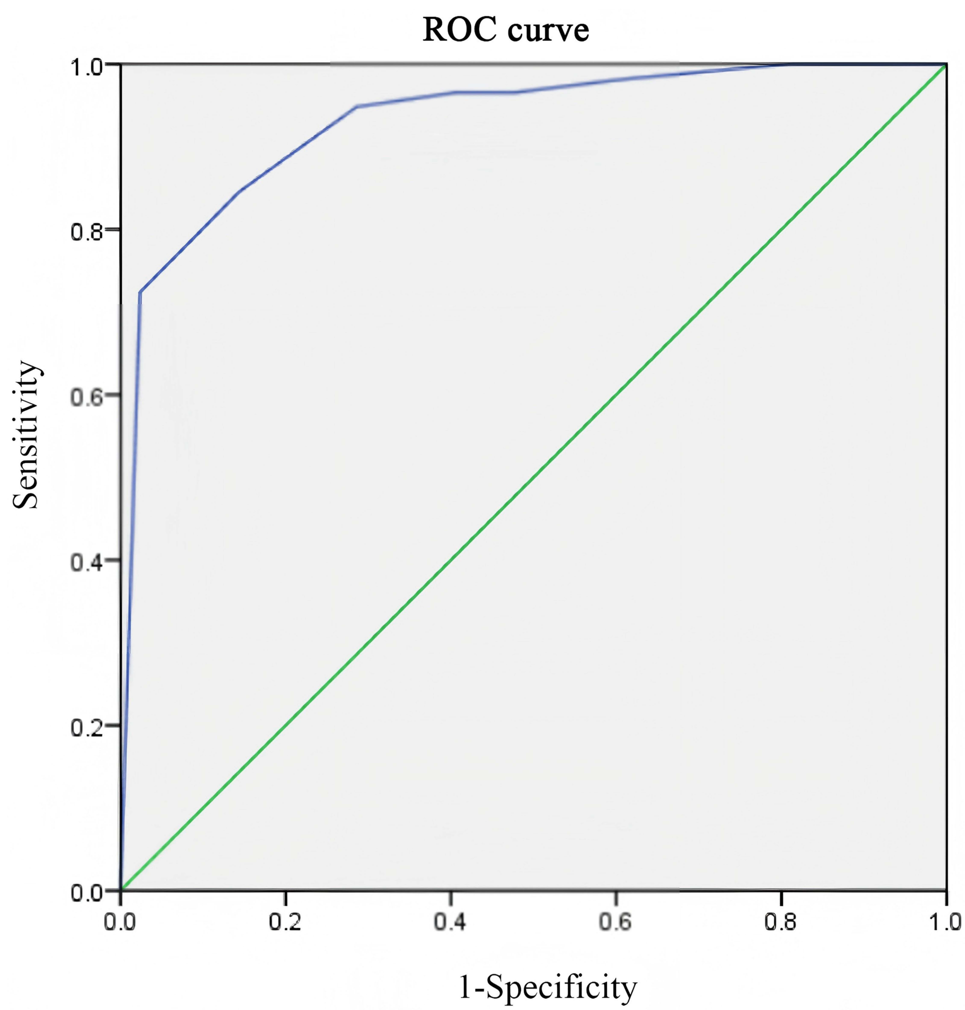

Figure 2 Nomogram for overall survival in patients with hepatocellular carcinoma after surgery.

compared between these two subgroups using the same statistical tests as for the primary analysis. The discriminative performance of the nomogram was then separately evaluated within each subgroup by calculating the area under the receiver operating characteristic curve (AUC).

The nomogram, ROC curve, calibration curve and clinical decision curve were plotted using R4.2.1 software to verify the accuracy and stability of the prediction model and to evaluate the clinical application value of the model.

Results

Comparison of General Data

Among the 200 patients, 116 (58%) achieved TO and 84 (42%) were non-TO. There were statistically significant differences between the TO group and the non-TO group in intraoperative blood loss, operative time, tumour diameter, postoperative hospital stay, nutritional risk score and malnutrition assessment ($P < 0.05$). All patients in this study achieved R0 resection, and there was no in-hospital mortality or postoperative 90-day mortality. The incidence of grade B/C biliary fistula was 6.5% (13/200), with 11 cases of grade B and 2 of grade C. The incidence of grade B/C liver failure was 5.5% (11/200), with 8 cases of grade B and 3 of grade C. The readmission rate for major postoperative complications within 90 days after surgery was 2.5% (5/200) (Table 1).

Table 1 Comparison of Clinical Data Between TO and Non-TO Hepatocellular Carcinoma Patients

Project		TO Group (n=116)	Non-TO Group (n=84)	(2	*P*
Age (x±s, year)		62.1±11.8	62.8±12.1	0.992	0.321
Gender [n(%)]	Male	100(86.2)	66(78.6)	2.013	0.156
	Female	16(13.8)	18(21.4)		
BMI (x±s,kg/m^2)		23.3±4.3	24.2±3.4	3.177	0.076
Hepatitis B [n(%)]	Yes	80(69.0)	52(61.9)	1.082	0.298
	No	36(31.0)	32(38.1)		
Long-term alcohol consumption history [n(%)]	Yes	22(19.0)	16(19.0)	0.000	0.988
	No	94(81.0)	68(81.0)		
Cirrhosis [n(%)]	Yes	56(48.3)	40(47.6)	0.008	0.927
	No	60(51.7)	44(52.4)		
Portal hypertension [n(%)]	Yes	16(13.8)	6(7.1)	2.201	0.138
	No	100(86.2)	78(92.9)		
Preoperative AFP (x±s,μg/L)		1159.5±7014.5	535.6±2128.2	2.219	0.138
Preoperative PLT (x±s,10^9/L)		156.3±58.3	170.1±76.6	0.808	0.370
Preoperative TBIL (x±s,μmol/L)		17.5±16.5	16.5±7.8	1.440	0.232
Preoperative ALT (x±s,U/L)		32.5±20.7	33.7±16.8	1.208	0.273
Preoperative AST (x±s,U/L)		38.2±25.2	35.6±13.7	2.066	0.152
Preoperative ALB (x±s,g/ L)		39.3±4.8	40.6±4.4	0.110	0.740
Intraoperative blood loss (x±s,mL)		133.1±126.0	496.7±528.4	106.088	0.000
Operation time (x±s,min)		184.8±88.4	242.7±122.5	8.916	0.003
Resection range [n(%)]	Small wedge resection	70(60.3)	56(66.7)	1.049	0.592
	Medium-sized hepatectomy	32(27.6)	18(21.4)		
	Extended hepatectomy	14(12.1)	10(11.9)		
Multiple tumors [n(%)]	Yes	18(15.5)	12(14.3)	0.058	0.810
	No	98(84.5)	72(85.7)		
Tumor diameter (x±s,cm)		3.0±1.6	4.4±3.0	11.494	0.001
Tumor stage [n(%)]	Ia	80(69.0)	60(71.4)	1.372	0.504
	Ib	26(22.4)	14(16.7)		
	IIa	10(8.6)	10(11.9)		

(*Continued*)

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Table 1 (Continued).

Project		TO Group (n=116)	Non-TO Group (n=84)	(2	*P*
Differentiation grade [n(%)]	Low	36(31.0)	34(40.5)	2.632	0.268
	Mid	74(63.8)	44(52.4)		
	High	6(5.2)	6(7.1)		
Microvascular invasion [n(%)]	M0	72(62.1)	50(59.5)	7.439	0.059
	M1	38(32.7)	24(28.6)		
	M2	6(5.2)	10(11.9)		
Postoperative hospital stay (x±s,d)		9.6±2.6	15.6±8.9	29.401	0.000
Nutritional risk [n(%)]	Yes	46(39.7)	74(88.1)	47.633	0.000
	No	70(60.3)	10(11.9)		
Malnutrition [n(%)]	Yes	6(5.2)	54(64.3)	81.070	0.000
	No	110(94.8)	30(35.7)		

Analysis of Influencing Factors of Textbook Outcome

Univariate and multivariate analyses showed that intraoperative blood loss, postoperative hospital stay and whether malnutrition was present were independent risk factors influencing the achievement of TO ($P < 0.05$). Further analysis indicated that intraoperative blood loss ≥225 mL, postoperative hospital stay ≥12.5 days and malnutrition assessed by the GLIM criteria were independent influencing factors for achieving TO postoperatively ($P < 0.05$, see Table 2).

Construction and Preliminary Validation of Nomogram Model

Based on the independent risk factors obtained from multivariate logistic regression analysis, a nomogram was constructed for the postoperative achievement of TO in patients with HCC (Figure 2). The C-index of the nomogram model was 0.931, and the area under the ROC curve for the nomogram model predicting postoperative achievement of TO in patients was 0.983 (95% CI: 0.971–0.995), with a sensitivity of 0.948 and a specificity of 0.929, indicating that the model had good predictive ability (Figure 3). The ideal curve fitted well with the calibration curve, indicating high prediction accuracy of the nomogram (Figure 4). Decision curve analysis showed good predictive efficacy of the nomogram model (Figure 5).

Subgroup Analysis Based on Extent of Liver Resection

To directly address the potential confounding effect of surgical complexity, we performed a subgroup analysis by reclassifying the patients. Based on the Brisbane 2000 nomenclature, small wedge resections were classified as Minor Resection (n=126), while medium-sized and extended hepatectomies were classified as Major Resection (n=74). The comparative analysis of these two subgroups is presented in Table 3. The Major Resection subgroup had a significantly larger tumor diameter (4.7 ± 2.8 cm vs 3.0 ± 1.6 cm, $P < 0.001$), longer operative time (250.8 ± 115.7 min vs 185.1 ± 89.3 min, $P < 0.001$), and greater intraoperative blood loss (480.1 ± 530.5 mL vs 180.5 ± 150.3 mL, $P < 0.001$). The rate

Table 2 Multivariate Logistic Regression Analysis of Factors Associated with Achieving TO After Surgery in Hepatocellular Carcinoma Patients

Project	*β*	Standard Deviation	*Wald*	*P*	*OR*	95% CI
Intraoperative blood loss	−2.344	0.599	15.332	0.000	0.096	0.030~0.310
Operation time	0.000	0.003	0.011	0.916	1.000	0.994~1.006
Tumor diameter	−0.120	0.134	0.799	0.372	0.887	0.681~1.154
Postoperative hospital stay	−2.793	0.556	25.258	0.000	0.061	0.021~0.182
Nutritional risk	−0.618	0.525	1.386	0.239	0.539	0.193~1.508
Malnutrition	−2.978	0.641	21.610	0.000	0.051	0.014~0.179

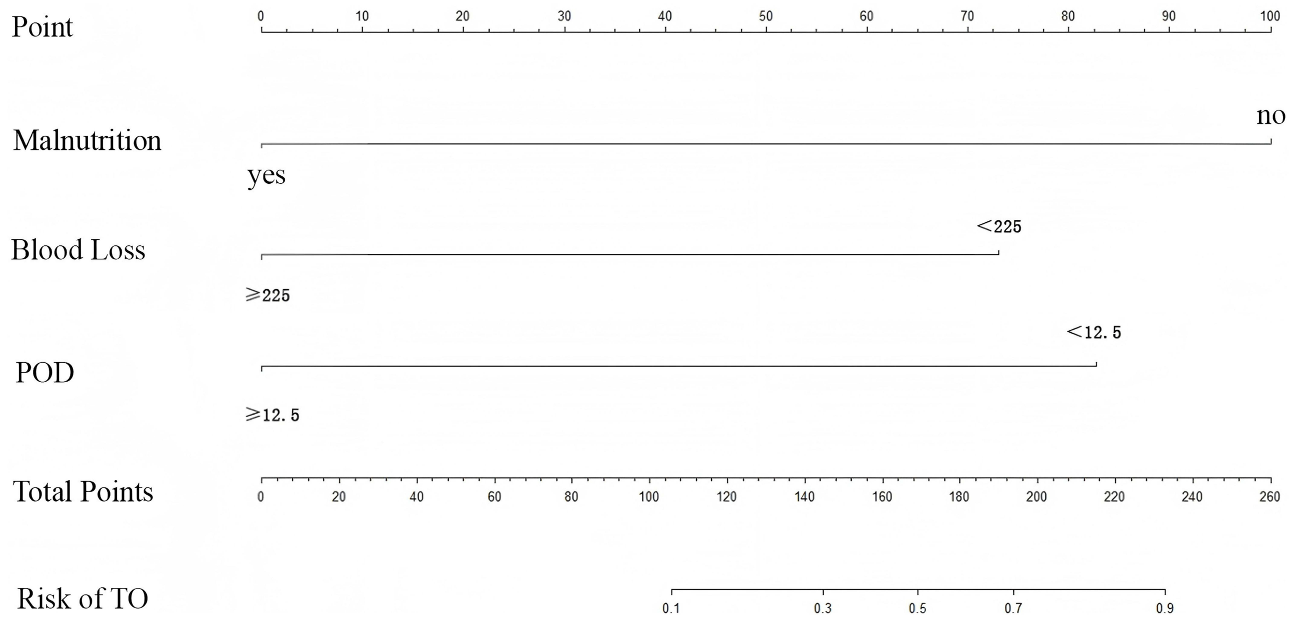

Figure 3 Nomogram predicted ROC curves for achieving TO after surgery in hepatocellular carcinoma patients.

of TO achievement was 61.9% in the Minor Resection subgroup and 51.4% in the Major Resection subgroup; this 10.5% absolute difference, while notable, did not reach statistical significance (P = 0.144) in our cohort. Crucially, the discriminative ability of the nomogram remained outstanding in both subgroups. The area under the ROC curve was 0.984 (95% CI: 0.970–0.998) for the Minor Resection subgroup and 0.976 (95% CI: 0.949–1.000) for the Major Resection subgroup, confirming the model's robust and consistent predictive performance across different levels of surgical complexity (Figure 6).

Discussion

In 2022, the IHPBA published an international expert consensus specifically for TOLS, recommending that medical units promote the application of this composite indicator to better help clinical discovery of the reasons affecting perioperative quality and continuously improve the progress of liver cancer diagnosis and treatment.[6–8] In this study, 116 patients achieved TO after surgery, and the TO probability was 58%, which is consistent with the results of previous studies.[17] However, it was lower than the study by Oji K et al, in which the TO probability of patients with liver cancer reached 72.7%;[18] the possible reasons for this are the following: (1) the cases included in that study were only stage Ia HCC, whereas the present study included stage Ib and IIa cases – tumour stage is an important factor affecting the postoperative clinical effect and prognosis of patients with liver cancer;[19] and (2) the TO evaluation criteria used were partially different from the international expert consensus on TOLS used in the present study, resulting in different results.

Previous studies have suggested that insufficient preoperative liver function reserve is an independent risk factor for patients with liver cancer not achieving TO,[20] which indirectly reflects the importance of adequate perioperative risk prediction for patient prognosis.

The results of this study showed that patients with HCC with intraoperative blood loss ≥225 mL, postoperative hospital stay ≥12.5 days and malnutrition assessed using the GLIM criteria achieved TO with greater difficulty after laparoscopic hepatectomy. In this study, the GLIM criteria were used to assess the preoperative nutritional status of patients with HCC, and it was confirmed that malnutrition defined by GLIM was an independent risk factor for not achieving TO after laparoscopic hepatectomy (odds ratio [OR] = 0.051). Previous studies have mostly used the ALBI grade or NRS2002 score, and although the results suggest that insufficient liver function reserve is negatively correlated with TO, they did not standardise the definition of "malnutrition". The GLIM criteria incorporate "low muscle mass" and "reduced intake" into the core phenotypic indicators, which can more sensitively capture the energy–protein imbalance

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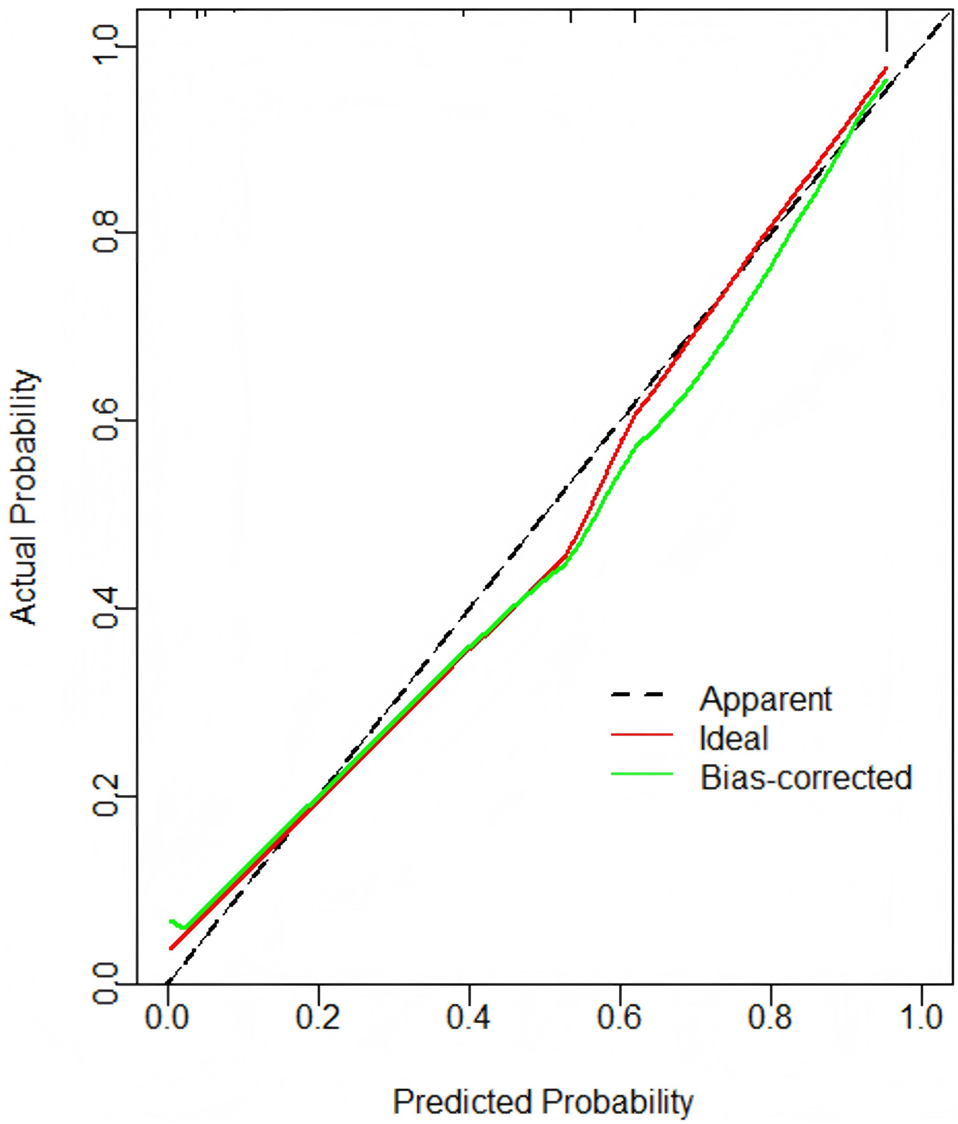

Figure 4 Calibration plot for predicting postoperative achievement of TO in hepatocellular carcinoma patients using nomogram.

caused by sarcopenia–inflammation–metabolic syndrome in patients with liver disease. The incidence of malnutrition in patients with liver cancer can be as high as 80%,[21] which is much higher than that of other malignant tumours. In this study, the incidence of malnutrition in patients with HCC screened by the GLIM criteria was 32%. The liver is the largest digestive organ and energy metabolism centre in the human body. When a tumour occurs, liver function is impaired, and the body experiences a series of manifestations such as decreased appetite and impaired digestion and absorption of nutrients. In addition, the interaction between tumour cells and inflammatory factors accelerates protein breakdown and consumes muscle cells, causing the body to gradually become malnourished.[22] Patients with liver cancer complicated by malnutrition before surgery have greater perioperative traumatic stress and higher surgical risks.[23] A large-sample meta-analysis fully demonstrated[24] that patients who received standardised immunonutritional support therapy during the perioperative period of hepatectomy had significantly reduced incidence of postoperative complications such as infection and liver failure and a significantly shortened hospital stay, indicating the importance of nutritional status for the clinical prognosis of patients with liver cancer. Therefore, an individualised GLIM-based immunonutritional intervention for 4–8 weeks before surgery is worth further validation in high-quality randomised controlled trials.

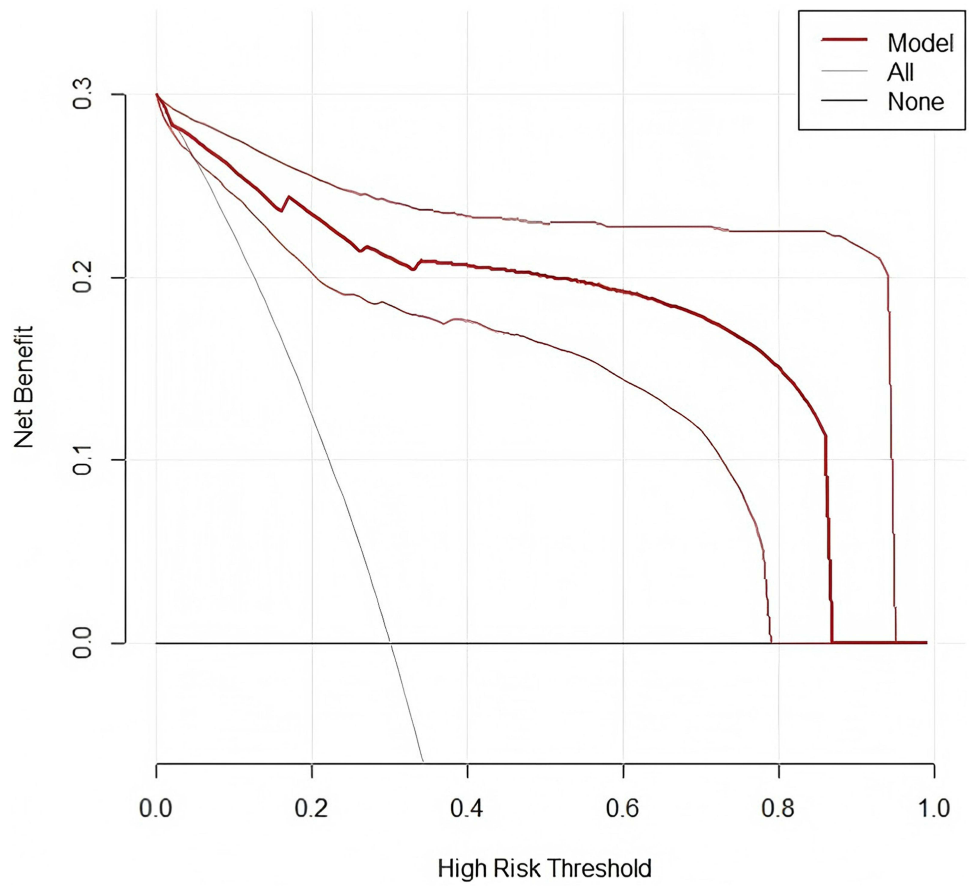

Figure 5 Decision curve analysis for predicting the achievement of TO nomogram in patients with hepatocellular carcinoma after surgery.

This study showed that intraoperative bleeding ≥225 mL significantly reduced the achievement rate of TO (OR = 0.096). This threshold is lower than the 300–500 mL reported in previous open hepatectomy series, suggesting that laparoscopic surgery has a lower tolerance for bleeding, which may be related to pneumoperitoneum pressure, limited operating space and difficulty in haemostasis. Our subgroup analysis further revealed that patients undergoing major resections had significantly greater blood loss (480.1 ± 530.5 mL vs 180.5 ± 150.3 mL, P < 0.001), underscoring the particular importance of meticulous haemostasis in more complex laparoscopic procedures. A retrospective study involving seven Asian centres indicated that for every 100-mL increase in blood loss, the probability of severe complications within 90 days after laparoscopic hepatectomy

Table 3 Subgroup Analysis: Comparison of Patient Characteristics and Outcomes Between Minor and Major Laparoscopic Liver Resection

Characteristic	Total Cohort (n=200)	Minor Resection (n=126)	Major Resection (n=74)	P-value
Demographics				
Age, years	62.4 ± 11.9	62.0 ± 11.7	63.1 ± 12.3	0.521
Male Gender	166 (83.0%)	107 (84.9%)	59 (79.7%)	0.343
BMI, kg/m^2	23.7 ± 3.9	23.4 ± 4.1	24.1 ± 3.5	0.205
Preoperative Data				
Hepatitis B	132 (66.0%)	88 (69.8%)	44 (59.5%)	0.131
Albumin (ALB), g/L	39.9 ± 4.6	40.1 ± 4.8	39.5 ± 4.3	0.374
Bilirubin (TBIL), µmol/L	17.1 ± 13.5	16.9 ± 14.1	17.4 ± 12.4	0.792

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Table 3 (Continued).

Characteristic	Total Cohort (n=200)	Minor Resection (n=126)	Major Resection (n=74)	P-value
Surgical & Pathological Data				
Tumor Diameter, cm	3.6 ± 2.3	3.0 ± 1.6	4.7 ± 2.8	<0.001
Operation Time, min	209.2 ± 106.1	185.1 ± 89.3	250.8 ± 115.7	<0.001
Intraoperative Blood Loss, mL	288.5 ± 385.2	180.5 ± 150.3	480.1 ± 530.5	<0.001
Blood Transfusion	27 (13.5%)	13 (10.3%)	14 (18.9%)	0.077
Microvascular Invasion (M1/M2)	78 (39.0%)	46 (36.5%)	32 (43.2%)	0.347
Postoperative Outcomes				
Postoperative Hospital Stay, days	12.2 ± 6.8	10.8 ± 3.9	14.6 ± 9.2	<0.001
Textbook Outcome (TO)	116 (58.0%)	78 (61.9%)	38 (51.4%)	0.144

Notes: Data are presented as mean ± standard deviation or n (%). Minor resection included small wedge resections; Major resection included medium-sized and extended hepatectomies. P-values compare the Minor and Major Resection groups, calculated using the independent samples *t*-test for continuous variables and the Chi-square test for categorical variables.
Abbreviation: BMI, Body Mass Index.

increased by 7%, and transfusion requirement was an independent predictor of TO failure. Intraoperative massive haemorrhage increases the risk of postoperative infection and liver dysfunction in patients with liver cancer.[25] Notably, patients with tumours with large intraoperative blood loss often have underlying factors such as advanced age, a large tumour diameter and multiple tumours; however, blood transfusion therapy itself can inhibit the immune function of patients with tumours.[26] The interaction of various complex mechanisms affects the clinical prognosis of patients. Therefore, promoting "precise haemostasis" strategies, such as low central venous pressure anaesthesia, regional inflow occlusion to the liver and combined application of energy devices, is of practical value for improving the TO rate.

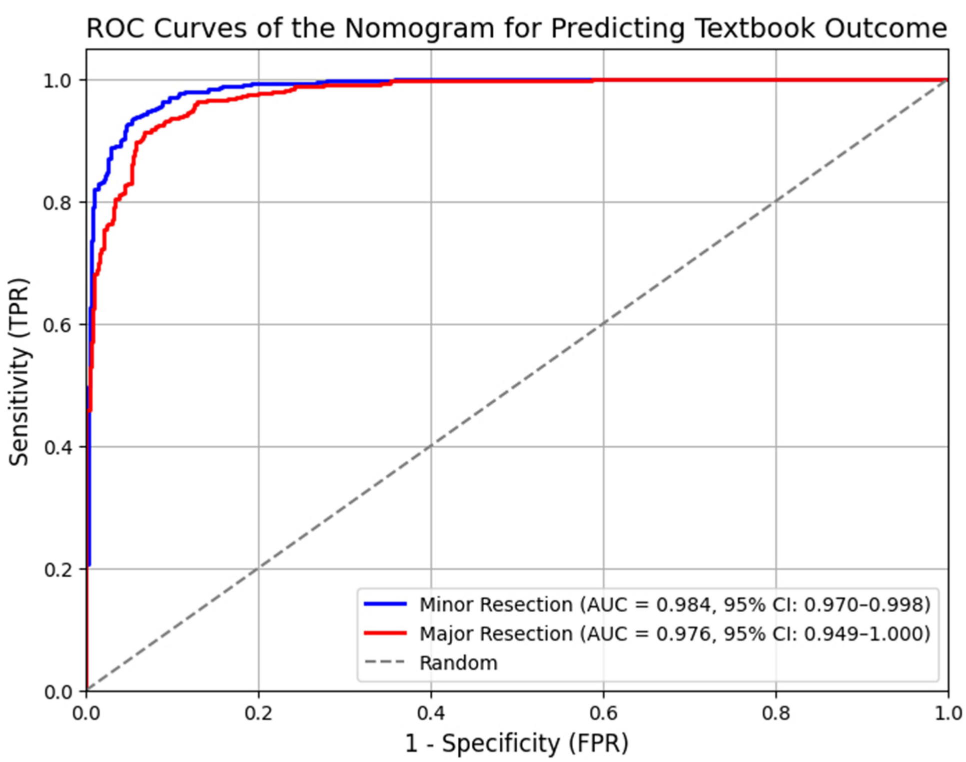

Figure 6 Receiver operating characteristic (ROC) curves of the nomogram for predicting textbook outcome in the minor and major liver resection subgroups.

In this study, postoperative hospitalisation ≥12.5 days was defined as a reverse indicator of TO (OR = 0.061). It is worth noting that prolonged hospitalisation may be the result of complications or a comprehensive manifestation of the combined effects of preoperative high-risk factors (such as malnutrition and diabetes) and surgical trauma. Our subgroup analysis corroborated this, showing that the major resection group had a significantly longer postoperative hospital stay (14.6 ± 9.2 days vs 10.8 ± 3.9 days, $P < 0.001$), which aligns with the increased physiological impact and potential for more complex recovery pathways associated with larger resections. Patients with prolonged postoperative hospitalisation for liver cancer often have underlying factors such as poor nutritional status[27] and chronic diseases[28] before surgery. In addition, compared with other organs, liver surgery has a high degree of difficulty, and the occurrence of perioperative complications prolongs postoperative hospitalisation to a certain extent.[29] This study did not find a direct correlation between length of stay and the 90-day readmission rate (the readmission rate was only 2.5%), suggesting that prolonged hospitalisation reflects delayed recovery rather than a "second hit". Therefore, the Enhanced Recovery After Surgery pathway – including early oral feeding, goal-directed fluid management and multidisciplinary early discharge assessment – may become an important handle for shortening the length of hospital stay and improving the TO rate.

Furthermore, the subgroup analysis provided critical validation of our nomogram's generalizability. Despite the significant differences in baseline tumor characteristics and surgical stressors between the minor and major resection groups, the nomogram demonstrated consistently excellent discriminative ability in both subgroups, with AUCs of 0.984 and 0.976, respectively. This robust performance across varying levels of surgical complexity strengthens the clinical utility of our model, suggesting that the identified predictors (malnutrition, blood loss, and hospital stay) are fundamental determinants of TO achievement, largely independent of the specific resection extent.

In recent years, the field of liver cancer diagnosis and treatment has been continuously updated and progressed, enabling more patients to benefit from surgery. However, the achievement rate of TO varies among different medical institutions, which is closely related to the medical level and surgical maturity of each unit. This study constructs a nomogram model based on preoperative nutritional status, intraoperative blood loss and postoperative length of hospital stay screened by univariate analysis and multivariate logistic regression. This model can effectively predict the probability of patients with liver cancer achieving TO after surgery.

This study has several limitations. First, it is a retrospective case–control study, and the included cases were only stage I and stage II, with a relatively small sample size, which may have some selection bias. Second, the cases in this study came from a single centre, and the model was not validated with external data. We hope to further expand the sample size in the future, combine multicentre case data for external validation, strengthen the performance and generalisation ability of the model and provide a strong basis for optimising the diagnosis and treatment of liver cancer and perioperative management.

Distinguishing whether death is caused by tumour progression or postoperative complications is crucial for a comprehensive assessment of surgical benefits. Due to the limited follow-up period, the focus of this study was on the short-term composite endpoint of TO, and fortunately, there were no deaths within 90 days in our study cohort, which precluded us from conducting a cause-of-death analysis. However, preoperative malnutrition and increased intraoperative blood loss, identified as key risk factors for TO achievement in our study, likely exert their negative impact by increasing the risk of severe complications (such as infection and liver failure), which are important causes of non-tumour-related deaths. Future studies that combine TO with long-term survival data that includes explicit cause-of-death information will be able to more clearly reveal the causal pathways between the components of TO (especially complications and death), thereby providing more targeted optimisation strategies for perioperative management.

Conclusion

In summary, TO can be used as a multi-dimensional, comprehensive and holistic index to evaluate the quality of liver cancer surgery. Preoperative malnutrition assessed by the GLIM criteria, intraoperative blood loss ≥225 mL and postoperative hospital stay ≥12.5 days are independent risk factors affecting the achievement of TO after laparoscopic hepatectomy in patients with HCC.

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The model constructed based on the above factors has good reliability and applicability and can help clinicians identify high-risk patients with non-TO early in the perioperative period, enabling them to implement timely and targeted interventions to improve prognosis.

Data Sharing Statement

All data generated or analyzed during this study are included in the article.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the First Affiliated Hospital of Ningbo University, with approval number: 2023 Research No. 079RS-01. Informed consent was signed by all participants in this study.

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Disclosure

The authors report no conflicts of interest in this work.

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