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Original Article

Predictive value of liver fibrosis markers and model for end-stage liver disease score in evaluating the degree of esophageal and gastric varices in cirrhosis

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Abstract: Objective: We aimed to investigate the predictive value of liver fibrosis (LF) markers and the Model for End-Stage Liver Disease (MELD) score in assessing the severity of esophageal and gastric varices (EGV) in patients with liver cirrhosis (LC). Methods: This retrospective study included 136 LC patients categorized by EGV severity into no EGV, mild EGV, moderate EGV, and severe EGV groups. Ordered multinomial logistic regression was used to identify independent risk factors, and multinomial ROC curves assessed the diagnostic performance of individual markers and combined models. Results: Hyaluronic acid (HA, r=0.867), laminin (LN, r=0.892), type IV collagen (CIV, r=0.885), type III procollagen N-terminal peptide (PIIINP, r=0.879), liver fibrosis 4 factor index (FIB-4, r=0.793), and MELD score (r=0.825) showed strong positive correlations with EGV severity (all *P*<0.01). After adjusting for confounding factors, including cirrhosis etiology, ascites, and hepatic encephalopathy, all these markers remained independent predictors of EGV severity. The combined model (HA+LN+CIV+PIIINP+FIB-4+MELD) demonstrated optimal diagnostic performance with an AUC of 0.89 (95% CI: 0.84-0.94), sensitivity of 83.6%, specificity of 81.2%, positive predictive value of 79.5%, and negative predictive value of 85.1%. Conclusion: The combined use of liver fibrosis markers and MELD score enables precise assessment of EGV severity in LC patients, providing a reliable non-invasive evaluation tool for clinical practice.

Keywords: Liver fibrosis, model for end-stage liver disease score, liver cirrhosis, esophageal and gastric varices

Introduction

Liver cirrhosis (LC) is a serious liver disease (LD) caused by the gradual replacement of normal liver tissue by fibrous tissue, resulting in persistent damage to liver structure and function. Surveys show that in 2019, death due to LC ranked 16th among all diseases, and most patients were middle-aged and elderly [1]. Additionally, the risk of LC is 18% higher for people with a Western diet than for those with a healthy diet [2]. Due to the progress of society, people's diet changes have increased the risk of LC. Elevated blood pressure in the portal vein system is a major complication of LC, which is caused by the increase of intrahepatic vascular resistance and the obstruction of blood reflux due to the damage of liver tissue [3]. The symptoms of patients with decompensated LC are mild, and some patients have no obvious symptoms. However, in the late stage of LC, the liver does not have compensatory function, and the patient's liver function decreases and the portal vein pressure increases. When portal hypertension occurs, blood has difficulty passing through the liver successfully. In people with LC, due to the influence of portal hypertension, blood will seek other pathways to return to the heart, one of which is through the esophageal, gastric fundus, and other venous system. These veins are not normally subjected to high pressure, but because of portal hypertension, the blood pressure in these veins increases, leading to venous dilatation, congestion, and eventually the formation of varicose veins [4, 5]. When varicose veins are enlarged, esophageal and gastric varices (EGV) are prone to rupture and bleeding, and the amount of bleeding can be life-threatening. Therefore, early detection and effective control of portal

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hypertension are essential for people with LC to reduce the occurrence of EGV and the risk of bleeding.

Studies have found that esophageal variceal bleeding has a mortality rate as high as 20% within 6 weeks after the onset of bleeding [6]. However, EGD is usually performed annually in patients with mild EGV and every 2 years in patients without EGV. The widespread use of noninvasive diagnostic methods in clinical practice has allowed LC to be diagnosed earlier in the effective compensatory stage than in previous decades, leading to a lower detection rate of EGV during initial EGD screening. The degree of LF is one of the main indicators to evaluate LC [7]. In the study by Plevris et al. (2018) [8], hyaluronic acid (HA) measurements had accurate and independent prediction in patients with LD. Some studies have used the model for end-stage liver disease (MELD) score to assess the prognosis and mortality of people with decompensated LC. ROC suggested that MELD score was a good predictor of one-month mortality in people with decompensated LC, and the sensitivity of death was 72.2% [9]. In the study of Huo et al. (2024) [10], AAR (Aspartate Aminotransferase (AST)/Alanine Aminotransferase (ALT) Ratio) was used to evaluate the prognosis of people with hepatocellular carcinoma after hepatectomy, and it was found that AAR≥1.4 was associated with shorter overall survival and recurrence-based survival in people with hepatocellular carcinoma after hepatectomy, indicating that AAR may be closely correlated with the development of liver function in people with hepatitis (cancer). In the study of Niu and Qi (2022) [11], the values of serum type IV collagen (IVC) and AAR were related to the development of liver fibrosis (LF), and serum IVC and AAR were markedly raised in people with LF, suggesting that serum IVC plus AAR had high diagnostic accuracy (Acc).

At present, there are no accurate indicators for the diagnosis of the degree of EGV in LC. This article was based on the non-invasive use of LF indicators, AAR, and MELD score to predict the degree of EGV in people with LC, in order to provide more accurate and early intervention methods to improve the prognosis of patients.

Materials and methods

Study subjects

This study was a retrospective study from December 2022 to December 2023, where 136 people with LC in Beijing Ditan Hospital Captital Medical University were selected, including 86 men and 50 women, with an average age of (53.12 ± 14.63) years, including 102 subjects with chronic LC after hepatitis B. There were 13 subjects with chronic LC after hepatitis C, 4 subjects with biliary LC, 9 subjects with fatty LC, 2 subjects with cholestatic LC, and 6 subjects with LC of unknown reason. The subjects were divided into four groups: Non-EGV, Mil-EGV, Mod-EGV, and Sev-EGV groups. Inclusion criteria: All patients were diagnosed according to the gold standard of the 2020 edition of the *Guidelines for the Diagnosis and Treatment of LC*; All patients underwent routine blood work, biochemical tests, and gastroscopy; The patients were not treated with endoscopic ligation, transvenous portosystemic shunt, etc.; The spleen was intact. Exclusion criteria: people with primary liver cancer or other malignant tumors; People with ascites or other factors affecting imaging examination; People with family history of thrombocytopenia; Patients taking drugs to lower portal pressure; People with severe organ dysfunction; Patients who underwent endoscopic variceal ligation and transvenous portosystemic shunt. This study was approved by the Ethics Committee of Beijing Ditan Hospital Captital Medical University.

Based on gastroscopy findings, the EGV grading criteria are as follows: (1) No EGV (Non-EGV): No dilated or tortuous veins observed in the esophagus or gastric fundus during gastroscopy; (2) Mild EGV: Veins appear linear or mildly tortuous, diameter <3 mm, without the red sign; (3) Moderate EGV: Veins show marked tortuosity with a beaded appearance, diameter 3-6 mm, may be accompanied by mild redness; (4) Severe EGV: Veins exhibit nodular, tumor-like dilation, diameter >6 mm, accompanied by marked redness or signs of rupture and bleeding.

Sample size calculation process: Sample size estimation was performed using PASS 15.0

software based on preliminary study results and relevant literature reports: Hyaluronic acid (HA) was designated as the primary predictor, with a correlation coefficient of r=0.743 against EGV severity. Setting α=0.05 (two-tailed), test power 1-β=0.90, and acceptable error δ=0.10, the formula yielded a minimum sample size of 112 cases. Accounting for a 20% dropout rate, the internal cohort sample size was finalized at 136 cases. The external validation cohort was set at 65 cases (50% of the internal cohort size) to ensure validation reliability. Subgroup sample distributions were as follows: Internal Cohort (n=136): Non-EGV (esophageal-gastric varices absent): 37 cases (27.2%); Mild EGV: 32 cases (23.5%); Moderate EGV: 35 cases (25.7%); Severe EGV: 32 cases (23.5%); External Validation Cohort (n=65): No esophageal-gastric varices (Non-EGV) 18 cases (27.7%), Mild EGV 16 cases (24.6%), Moderate EGV: 15 cases (23.1%); Severe EGV: 16 cases (24.6%).

AST/ALT, AAR detection

The samples collected were used to detect the levels of ALT and AST in the serum of patients using TBA-120FR automatic biochemical analyzer (Beijing Canon Medical Systems (China) Co., Ltd., China). The calculation method for the aminotransferase ratio (AAR) was: AAR = Serum aspartate aminotransferase (AST) test value/Serum alanine aminotransferase (ALT) test value (both units in U/L).

Platelet count (PLT) detection

PLT values in the serum of patients were detected using BC-5000 automatic blood cell analyzer (Shenzhen Mindray Bio-Medical Electronics Co., Ltd., China).

Indicators of LF

(1) Serum LF indicators of subjects

Five mL of fasting venous blood was obtained in the morning, and the serum was preserved after centrifugation. Serum HA, LN, type IV collagen (CIV), and PIIINP were detected by SUPERFLEX® automatic chemiluminescence immunoassay analyzer (PerkinElmer Inc., Jiangsu, China). Chemiluminescence and magnetic microparticle separation technology was adopted (normal range: HA<120 ng/mL, LN<130 ng/mL, CIV<95 ng/mL, PIIINP<15 ng/mL).

(2) Indicators of LF model of subjects

$$\text{FIB-4} = \text{Age} \times \frac{\text{AST}}{\text{PLT}} \times \text{ALT}^{\frac{1}{2}} \quad (1)$$

Note: The units of AST and ALT are U/L; PLT is measured in 10^9/L.

MELD score calculation

The PUZS-600A/B automatic biochemical analyzer (Beijing Perlong New Technology Co., LTD., Beijing, China) was used to detect the serum creatinine (Cr), total bilirubin (TBIL), and prothrombin time (PT) of subjects. The international normalized ratio (INR) and MELD score were calculated according to the following equation.

MELD score ≤15 was defined as low-risk subjects; >15, ≤24 were moderate-risk subjects; >24 subjects were defined as high risk.

$$\text{INR} = \text{PT}^{\text{ISI}} \quad (2)$$

Note: ISI is the sensitivity index marked by thromboplastin reagent.

$$\text{MELD} = 3.78 \times \ln\text{TBIL}\left(\frac{\text{mg}}{\text{dl}}\right) + 11.2 \times \ln\text{INR} + 9.5 \times \ln\text{Cr}\left(\frac{\text{mg}}{\text{dl}}\right) + 6.4 \times \textit{Etiologycorrectionfactor} \quad (3)$$

Note: (0, 1): biliary or alcoholic LC is 0, and other LC is 1.

External validation cohort

To verify the stability of the aforementioned LF indicators (HA, LN, CIV, PIIINP, FIB-4) and the MELD score in jointly assessing the degree of EGV in patients with LC, 65 LC patients from another tertiary hospital between January 2023 and January 2024 were selected as the external validation cohort. The inclusion and exclusion criteria were the same as in Section 2.1, and the patients were divided into Non-EGV, Mil-EGV, Mod-EGV, and Sev-EGV groups based on endoscopic results. The data for each indicator were obtained using the same detection methods consistent with the internal cohort, the combined indicator (HA+LN+CIV+PIIINP+FIB-4+MELD) was calculated, and its diagnostic efficacy was analyzed.

Table 1. Comparison of baseline data for esophageal and gastric varices (EGV) in patients with liver cirrhosis

Variable	No EGV Group (n=37)	Mild EGV Group (n=32)	Moderate EGV Group (n=35)	Severe EGV Group (n=32)	Statistic	*P* Value
Gender (Male/Female)	22/15	12/20	21/14	9/23	χ^2=1.876	0.597
Age (years)	47.13±12.64	52.36±13.05	55.78±12.81	56.94±13.52	F=4.283	0.006
Hyaluronic Acid (HA, ng/mL)	113.62±21.52	198.45±32.17	276.38±40.59	312.67±45.82	F=189.652	<0.001
Laminin (LN, ng/mL)	87.53±14.26	105.72±20.34	128.96±24.18	143.25±26.73	F=42.895	<0.001
Type IV Collagen (CIV, ng/mL)	59.52±10.51	112.36±18.75	165.89±22.41	196.42±25.38	F=216.378	<0.001
Type III Procollagen N-Terminal Peptide (PIIINP, ng/mL)	8.96±1.14	11.78±2.35	14.92±3.16	16.85±4.02	F=68.743	<0.001
Fibrosis-4 (FIB-4) Index	1.89±0.37	3.62±0.85	6.05±1.57	7.98±2.13	F=127.546	<0.001
Alanine Aminotransferase (ALT, U/L)	24.68±8.53	25.94±9.01	28.17±9.32	29.65±8.97	F=1.562	0.202
Aspartate Aminotransferase (AST, U/L)	28.15±8.12	28.76±8.35	29.89±8.51	30.62±8.73	F=0.387	0.763
Platelet Count (PLT, 10^9/L)	203.12±26.63	145.78±25.36	108.45±22.67	89.62±18.95	F=156.284	<0.001
AST/ALT Ratio (AAR)	1.36±0.23	1.32±0.21	1.27±0.24	1.25±0.22	F=1.035	0.377
Model for End-Stage Liver Disease (MELD) Score	13.11±2.41	16.85±2.97	21.36±3.52	24.78±4.13	F=78.965	<0.001

Note: EGV: esophageal and gastric varices; LC: liver cirrhosis; HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; ALT: alanine aminotransferase; AST: aspartate aminotransferase; AAR: AST/ALT ratio; MELD: model for end-stage liver disease; PLT: platelet count.

Data analysis

SPSS 27.0 software was employed. First, the normality of the quantitative data was verified using the Shapiro-Wilk test: Measurement data were presented as mean ± sd ($\overline{x}$±s), and *t* test was adopted. The count data were presented as the number of cases (%), and the chi-square test was adopted. Spearman correlation analysis (SCA) was adopted to detect the correlation of indicators and EGV degree, |r| closer to 1, the stronger the correlation. Ordered multinomial logistic regression analysis was employed to identify independent factors influencing EGV severity, with the dependent variable being EGV grading (0 = no EGV, 1 = mild EGV, 2 = moderate EGV, 3 = severe EGV). Independent variables included liver fibrosis markers (HA, LN, CIV, PIIINP, FIB-4), MELD score, and confounding factors (gender, age, cirrhosis etiology). Based on the independent risk factors (HA, LN, CIV, PIIINP, FIB-4, MELD score) identified through ordered multicategorical logistic regression analysis, a combined prediction model for EGV severity was constructed. This model was designed as a weighted scoring model, with weights determined based on the standardized regression coefficients of each variable. The specific calculation logic was as follows: Total model score = 0.22 × HA + 0.28 × LN + 0.25 × CIV + 0.08 × PIIINP + 0.10 × FIB-4 + 0.07 × MELD. In the above formula, the standardized regression coefficients (β values) for each indicator were derived from the results of the ordinal multinomial logistic regression analysis. These coefficients had eliminated differences in indicator units, allowing indicators with varying units to be directly weighted and summed. By assigning corresponding weights to each indicator through standardized regression coefficients, it was ensured that indicators with different units of measurement could be directly summed. The total score was used to quantify the risk of EGV severity. Model applicability was validated using the proportional odds hypothesis test, and model goodness-of-fit was assessed via the Hosmer-Lemeshow test. Diagnostic accuracy (Acc) for EGV severity was evaluated for individual markers and combined marker panels using receiver operating characteristic (ROC) curve analysis. *P*<0.05 was considered statistically meaningful.

Results

Analysis of subjects' general data

Among 136 patients with cirrhosis, 99 were diagnosed with esophagogastric varices, while the remaining 37 had no varices (**Table 1**). Further subgroup analysis was performed based on variceal severity, dividing the subjects into a no-varices group, a mild-varices group, a moderate-varices group, and a severe-varices group. Age analysis revealed no significant difference between the no-varices group and the varices group (*P*>0.05), although age tended to increase with worsening variceal severity. Comparison of liver fibrosis indicators showed

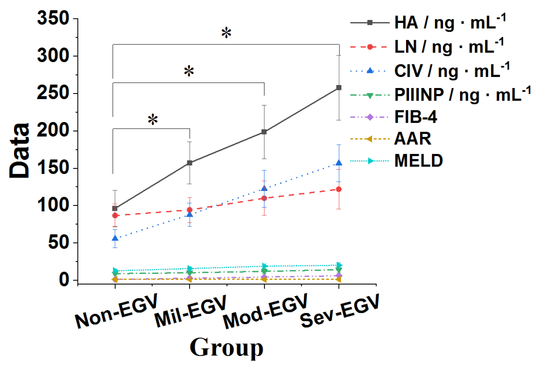

Figure 1. Contrast of various indicators among subjects with different degrees of EGV. Note: EGV: esophageal and gastric varices; LF: liver fibrosis; HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; AAR: AST/ALT ratio; MELD: model for end-stage liver disease. Compared with the Non EGV group, $P<0.05$.

that levels of hyaluronic acid, laminin, type IV collagen, N-terminal propeptide of type III procollagen, and the FIB-4 index were all significantly higher in the varices group than in the no-varices group ($P<0.05$). Analysis based on the AST/ALT ratio indicated no significant difference in AST and ALT values between the varices group and the no-varices group ($P>0.05$), and there was also no significant difference across subgroups of different variceal severities. MELD score analysis showed that the MELD score was significantly higher in the varices group than in the no-varices group ($P<0.05$), and the MELD score progressively increased with worsening variceal severity, reflecting a close association between liver reserve function and the severity of varices.

Additionally, platelet count was significantly lower in the varices group than in the no-varices group ($P<0.05$) and gradually decreased with increasing variceal severity, which was consistent with the clinical manifestation of portal hypertension affecting hematopoietic function. No significant difference in gender distribution was observed between the varices group and the no-varices group, or among subgroups of different variceal severities ($P>0.05$).

Contrast of indexes among subjects with different EGV degrees

The distinctions of LF indexes, AAR, and MELD score in subjects with different EGV degrees were analyzed (**Figure 1**). As against Non-EGV subjects, the HA, LN, CIV, PIIINP, FIB-4, and MELD score of subjects with Mil-EGV, Mod-EGV, and Sev-EGV were markedly raised. However, there was no visible distinction in AAR value among subjects.

Table 2. SCA of correlation of fibrosis indicators, MELD score and EGV degree

Variables	Correlation coefficient *r*	*P*-value
HA (ng/mL)	0.867	0.001
LN (ng/mL)	0.892	0.001
CIV (ng/mL)	0.885	0.001
PIIINP (ng/mL)	0.879	0.001
FIB-4	0.793	0.003
MELD	0.825	0.002

Note: SCA: Spearman correlation analysis; EGV: Esophageal and Gastric Varices; HA: Hyaluronic Acid; LN: Laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; MELD: model for end-stage liver disease.

SCA to analyze the correlation between fibrosis index, MELD score and EGV degree

Spearman correlation analysis (SCA) was employed to investigate the correlation between liver fibrosis markers, Model for End-Stage Liver Disease (MELD) scores, and the severity of EGV. Results (**Table 2**; **Figure 2**) showed that as EGV severity progressively increased from non-EGV, mild EGV, moderate EGV, to severe EGV, levels of hyaluronic acid (HA), laminin (LN), CIV, procollagen type III N-terminal peptide (PIIINP), FIB-4 index, and MELD score all showed a significant upward trend. All measured indicators exhibited strong positive correlations ($|r|>0.7$) with EGV severity, with statistically significant differences (all $P<0.01$).

Multivariate logistic regression analysis (LRA) to analyze the relationship between fibrosis indicators, and MELD score and the degree of EGV

Using ordered multinomial logistic regression analysis, we investigated the independent associations between liver fibrosis markers and MELD scores with EGV severity, while adjusting for gender, age, and cirrhosis etiology (HBV/other) as confounding factors to control for potential bias. The proportional odds hypothesis test yielded $P=0.132$, and the Hosmer-Lemeshow test showed $\chi^2=7.015$, $P=$

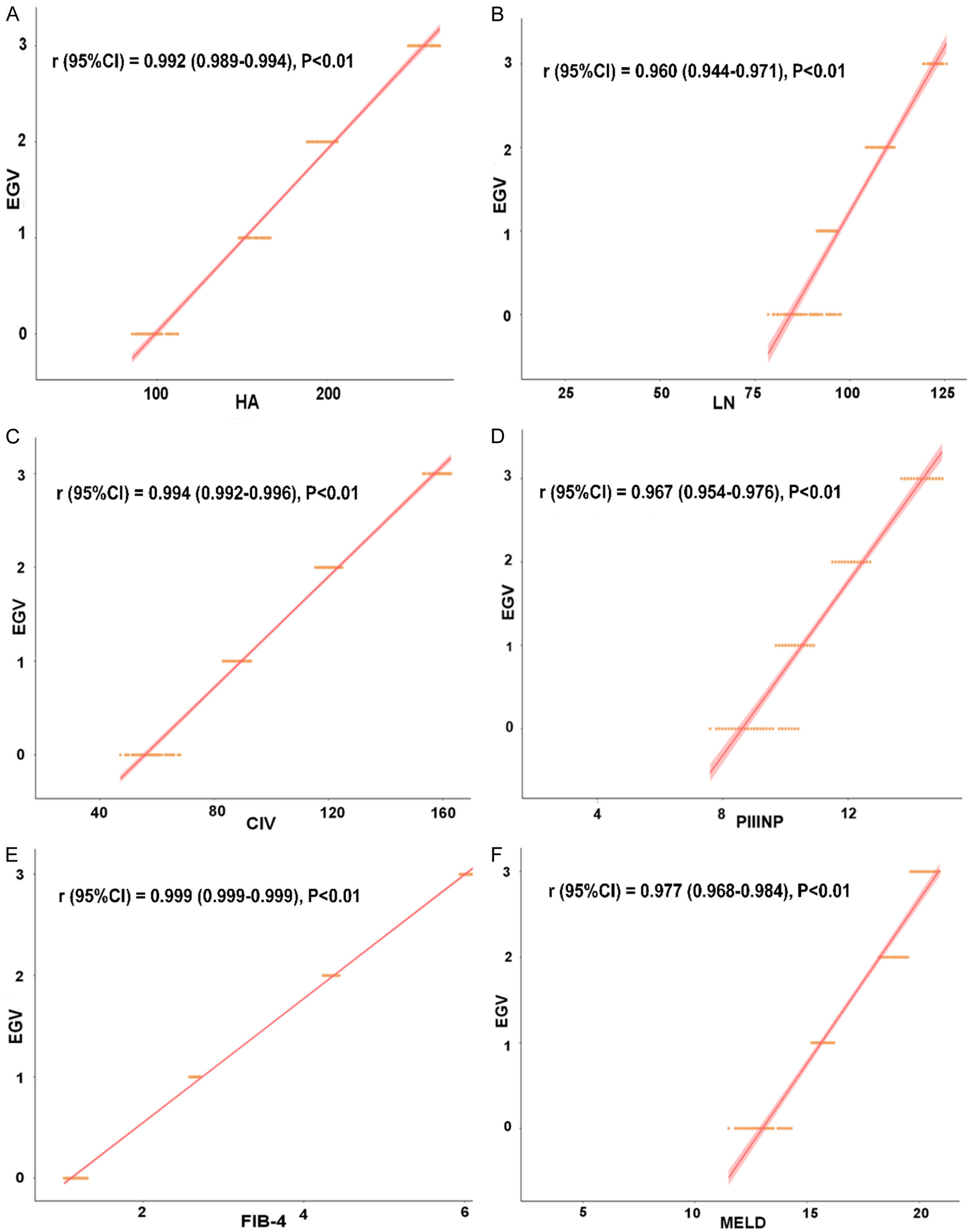

Figure 2. Correlation between fibrosis markers, MELD Score, and EGV severity (A-F: HA, LN, CIV, PIIINP, FIB-4, MELD). Note: EGV: esophageal and gastric varices; HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; MELD: model for end-stage liver disease.

0.535, indicating good model fit and compliance with ordered regression assumptions.

Before adjusting for confounders (**Table 3**), HA, LN, CIV, PIIINP, FIB-4, and MELD score were

Table 3. Multivariate LRA of the relationship between fibrosis indicators, AAR, MELD score and the degree of EGV

	OR	χ^2	95% CI		*P*-value
			Lower limit	Upper limit	
HA (ng/mL)	1.623	7.15	1.15	2.28	0.008
LN (ng/mL)	1.845	12.69	1.32	2.57	0.001
CIV (ng/mL)	1.702	9.34	1.24	2.33	0.002
PIIINP (ng/mL)	1.651	7.58	1.17	2.33	0.006
FIB-4	1.796	8.12	1.26	2.55	0.004
MELD	1.789	5.26	1.13	2.82	0.022

Note: LRA: Logistic regression analysis; EGV: esophageal and gastric varices; HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; AAR: AST/ALT ratio; MELD: model for end-stage liver disease; OR: odds ratio; CI: confidence interval. The OR values of continuous variables are calculated based on specified unit increments to avoid exaggerating the effect size and clarify clinical significance.

Table 4. Results of ordered multiclass logistic regression analysis for liver fibrosis markers, MELD Score, and EGV Severity (adjusted for baseline characteristics)

	OR	χ^2	95% CI		*P*-value
			Lower limit	Upper limit	
HA (ng/mL)	1.597	6.83	1.12	2.26	0.01
LN (ng/mL)	1.812	11.95	1.29	2.53	0.001
CIV (ng/mL)	1.675	8.92	1.21	2.31	0.003
PIIINP (ng/mL)	1.628	7.21	1.14	2.31	0.007
FIB-4	1.763	7.75	1.23	2.52	0.005
MELD	1.756	4.98	1.10	2.79	0.026
Gender (Male vs Female)	1.103	0.18	0.67	1.82	0.672
Age (years)	1.018	3.76	1.00	1.04	0.053
Cause of liver cirrhosis (hepatitis B vs other)	1.087	0.12	0.65	1.81	0.731

Note: EGV: esophageal and gastric varices; HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; MELD: model for end-stage liver disease; OR: odds ratio; CI: confidence interval. The OR values of continuous variables are calculated based on specified unit increments to avoid exaggerating the effect size and clarify clinical significance.

all risk factors for EGV severity (all P<0.05). Ordered multicategorical logistic regression analysis showed that for every 50 ng/mL increase in HA, the risk of progression in EGV severity was increased by 62.3% (OR=1.623, 95% CI: 1.15-2.28, *P*=0.008). For every 50 ng/mL increase in LN, the risk was increased by 84.5% (OR=1.845, 95% CI: 1.32-2.57, *P*=0.001). For every 50 ng/mL increase in CIV, the risk was increased by 70.2% (OR=1.702, 95% CI: 1.24-2.33, *P*=0.002). For every 50 ng/mL increase in PIIINP, the risk was increased by 65.1% (OR=1.651, 95% CI: 1.17-2.33, *P*=0.006). For every 1-unit increase in FIB-4, the risk was increased by 79.6% (OR=1.796, 95% CI: 1.26-2.55, *P*=0.004). For every 5-point increase in MELD score, the risk was increased by 78.9% (OR=1.789, 95% CI: 1.13-2.82, *P*=0.022). After adjusting for sex, age, and cirrhosis etiology (**Table 4**), these indicators remained independent risk factors for EGV severity (all *P*<0.05), with no significant fluctuation in OR values, indicating good result stability. However, gender (OR=1.103, *P*=0.672), age (OR=1.018, *P*=0.053), and cause of cirrhosis (OR=1.087, *P*=0.731) had no significant impact on EGV severity.

Building predictive models and drawing regression lines

Based on independent risk factors identified through ordered multinomial logistic regression, a severity prediction model for EGV incorporating HA, LN, CIV, PIIINP, FIB-4, and MELD scores was constructed, with a nomogram generated (**Figure 3**). By quantifying individual scores and the total score, this model intuitive-

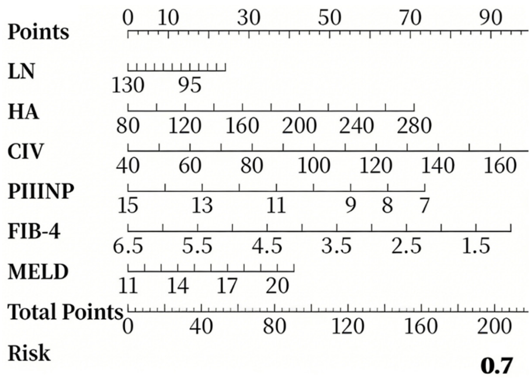

Figure 3. Prediction model scatter plot. Note: EGV: esophageal and gastric varices; HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; MELD: model for end-stage liver disease. The scores corresponding to each indicator in the column chart are calculated based on the standardized weights in **Table 6**, with a total score range of 0-300 points. The higher the score, the higher the severity of EGV. After accumulating the scores of all indicators, the predicted probabilities of different EGV severity levels can be read through the probability axis on the right.

ly predicts the probability of patients developing EGV at different severity levels. Its simplicity and high visual ability provide a practical tool for individualized clinical assessment.

The clinical utility of the predictive model was evaluated via decision curve analysis (DCA, **Figure 4**): When the high-risk threshold was set between 0 and 0.8, the model developed in this study (blue curve) demonstrated significantly greater net benefit compared to both the "all intervention" (red curve) and "no intervention" (green curve) strategies. This indicates that the model effectively identifies high-risk patients who genuinely require intervention, demonstrating strong clinical utility.

The regression coefficients and standardized weights for each variable in the combined prediction model are presented in the table below (**Table 5**). Following ordered multicategorical logistic regression analysis, all indicators yielded regression coefficients with significant statistical significance ($P<0.05$). The standardized weights reflect the strength of their influence on EGV severity: LN had the highest weight (0.28), followed by CIV (0.25) and HA (0.22), while FIB-4 (0.10), PIIINP (0.08), and the MELD score (0.07) had relatively lower weights.

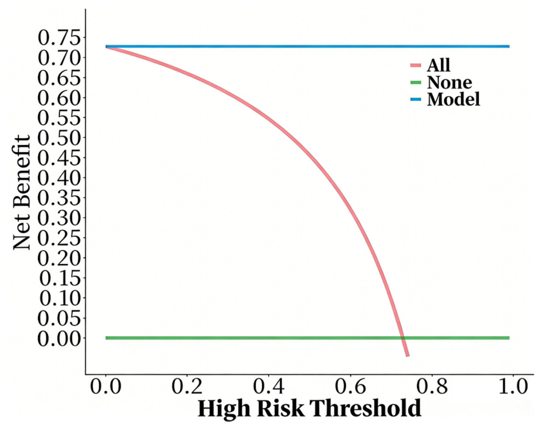

Figure 4. Model DCA curve. Note: DCA: decision curve analysis; EGV: esophageal and gastric varices.

ROC curve analysis results

A one-versus-one (One-vs-One) strategy was adopted for multiclass ROC curve analysis. ROC models were constructed for all category pairs (non-EGV vs mild EGV, non-EGV vs moderate EGV, non-EGV vs severe EGV, mild EGV vs moderate EGV, mild EGV vs severe EGV, moderate EGV vs severe EGV). The weighted average AUC was then calculated using the proportion of sample sizes for each pair as the weight. As a result, a comprehensive AUC value of 0.89 (95% CI: 0.84-0.94) was obtained for the combined prediction model. This approach comprehensively reflects the model's ability to differentiate between varying levels of EGV severity. Multiple-class ROC curve analysis was employed to evaluate the predictive performance of individual liver fibrosis markers, MELD score, and the combined predictive model (HA+LN+CIV+PIIINP+FIB-4+MELD) for EGV severity (**Figure 5**). Optimal cutoff values for each marker and the model were determined using the maximum Youden index method, with sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Results showed that the AUC of the combined predictive model was 0.89 (95% CI: 0.84-0.94), significantly higher than all individual markers (AUC range: 0.67-0.78). With combined sensitivity, specificity, PPV, and NPV reaching 83.6%, 81.2%, 79.5%, and 85.1%, respectively. This demonstrated optimal overall diagnostic performance, effectively distinguishing patients with different EGV severity levels. Specific diagnostic parameters for each indicator and model are presented in **Table 6**.

Table 5. Diagnostic performance metrics for predicting EGV severity using individual indicators and combined models

Variable	Regression coefficient (B)	Standard Error (SE)	χ^2 Value	*P* Value	Standardized regression coefficient (β)	Model weights
HA (ng/mL)	0.012	0.003	16.28	0.001	0.22	0.22
LN (ng/mL)	0.018	0.004	20.15	0.001	0.28	0.28
CIV (ng/mL)	0.015	0.003	18.76	0.001	0.25	0.25
PIIINP (ng/mL)	0.009	0.003	9.32	0.002	0.08	0.08
FIB-4	0.011	0.004	8.57	0.003	0.1	0.1
MELD Rating	0.008	0.003	7.24	0.007	0.07	0.07

Note: HA: hyaluronic Acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; MELD: model for end-stage liver disease; SE: standard error. The model weight is calculated based on normalized regression coefficients (weight of a certain indicator = β value of that indicator/sum of β values of all indicators), ensuring that the total weight is 100%.

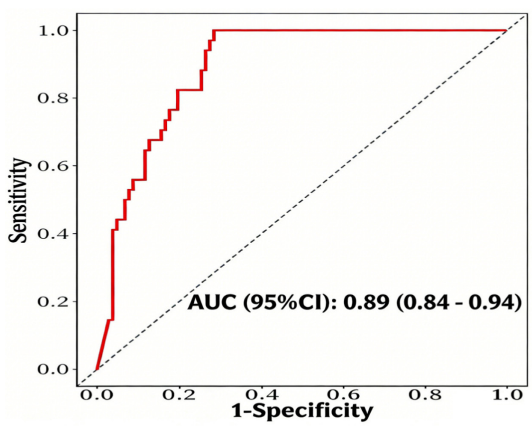

Figure 5. Model ROC curve. Note: ROC: Receiver Operating Characteristic; AUC: area under the curve; CI: confidence interval; EGV: esophageal and gastric varices.

SHapley Additive exPlanations (SHAP) analysis further elucidated the contribution and directional influence of each indicator within the model (**Figures 6** and **7**). SHAP dependency plots revealed strong correlations between SHAP values and core indicators such as FIB-4, CIV, and HA showed strong correlations between feature values and SHAP values. Among these, FIB-4 (feature value 1.18) had the strongest negative contribution to model predictions (SHAP value -162), while CIV (feature value 60.5) exhibited the most significant positive contribution (SHAP value +105). The SHAP summary plot visually demonstrates that lower feature values for indicators like FIB-4 and MELD score exert stronger negative suppression on "high EGV risk", while higher feature values for indicators such as HA, CIV, and LN show more pronounced positive promotion of "high EGV risk". This clarifies the weighting and mechanism of action for each indicator within the model, enhancing its clinical interpretability.

External validation of the combined prediction model

To validate the stability and generalizability of the combined prediction model (HA+LN+CIV+PIIINP+FIB-4+MELD), 65 patients with cirrhosis were included as an external validation cohort (**Table 7**). The inclusion and exclusion criteria were consistent with those of the internal cohort. Based on gastroscopy findings, patients were categorized into non-severe EGV (18 cases, 27.7%), mild EGV (16 cases, 24.6%), moderate EGV (15 cases, 23.1%), and severe EGV (16 cases, 24.6%). All indicators were measured using the same methods as in the internal cohort, and the diagnostic performance of the combined model was evaluated. The results demonstrated that the combined model maintained excellent performance in the external cohort: AUC=0.86 (95% CI: 0.78-0.93), sensitivity = 80.3%, specificity = 78.5%, positive predictive value = 76.2%, negative predictive value = 82.1%. These findings confirm the reliable stability and clinical applicability of the model across different patient populations.

Discussion

EGV represent a significant complication of portal hypertension in liver cirrhosis, with high mortality rates associated with their rupture and bleeding. Therefore, early and accurate assessment of EGV severity is crucial for clinical intervention decisions. Although gastrosco-

Table 6. Diagnostic performance metrics for predicting EGV severity using individual indicators and combined models

Variables	AUC	95% CI	Optimal cutoff value	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
HA (ng/mL)	0.76	0.70-0.82	189.5	75.3	72.1	70.4	77
LN (ng/mL)	0.78	0.72-0.84	106.8	76.5	73.4	71.8	78
CIV (ng/mL)	0.77	0.71-0.83	108.2	77.2	74.6	72.9	78.7
PIIINP (ng/mL)	0.72	0.65-0.78	11.7	71.4	68.9	67.3	72.9
FIB-4	0.75	0.69-0.81	4.26	73.8	70.5	68.8	75.4
MELD	0.67	0.60-0.74	16.8	69.3	65.7	64.1	70.8
Joint prediction model	0.89	0.84-0.94	156.3	83.6	81.2	79.5	85.1

Note: EGV: esophageal and gastric varices; HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; MELD: model for end-stage liver disease; AUC: area under the curve; CI: confidence interval; PPV: positive predictive value; NPV: negative predictive value.

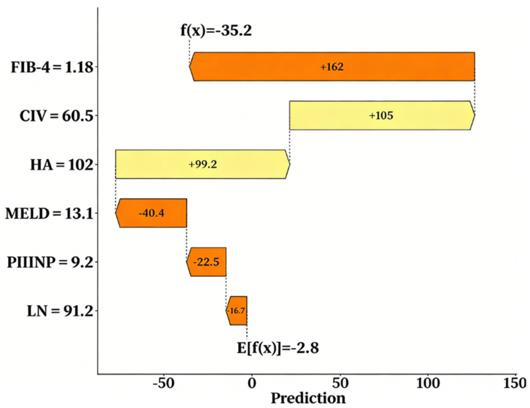

Figure 6. Model single-sample waterfall plot. Note: HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; MELD: model for end-stage liver disease; SHAP: SHapley Additive exPlanations.

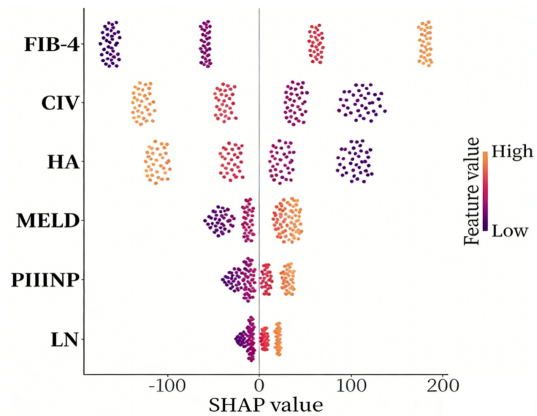

Figure 7. Model feature cluster plot. Note: HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; MELD: model for end-stage liver disease; SHAP: SHapley Additive exPlanations.

py is the gold standard for diagnosis, it has limitations such as invasiveness, high examination costs, and poor patient tolerance. It is particularly difficult to use as a routine screening tool in primary care hospitals or for patients with severe underlying diseases [12-15]. Duan et al. [16] also noted in their study on endoscopic treatment for EGV rupture bleeding (EGVB) in cirrhosis that complications associated with EGV (such as portal vein thrombosis and cholelithiasis) significantly impact patient prognosis. Early and accurate assessment of EGV severity is a key prerequisite for optimizing intervention strategies and reducing complications, aligning with the core objective of this study. Based on this, developing efficient, convenient, and non-invasive predictive tools has become a key focus in clinical research. Through systematic analysis of liver fibrosis markers and MELD scores in cirrhotic patients, this study identified significant positive correlations between HA, LN, CIV, PIIINP, FIB-4, and MELD scores with EGV severity. Ordered multinomial logistic regression validation confirmed these markers as independent risk factors for EGV severity. This finding aligns closely with clinical-pathological mechanisms: liver fibrosis is the core pathological process in cirrhosis progression. As fibrosis worsens, hepatic vascular resistance increases and portal vein pressure rises, leading to compensatory dilation and tortuosity of EGV, ultimately forming varices [17, 18]. HA, as a sensitive indicator of liver fibrosis activity, directly reflects the progression of hepatic fibrosis when elevated. LN and CIV primarily participate in the formation of the sinu-

Table 7. Diagnostic performance metrics of individual indicators and combined model in external validation cohort

Variables	AUC	95% CI	Optimal cutoff value	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
HA (ng/mL)	0.73	0.65-0.81	192.7	72.4	69.8	67.5	74.6
LN (ng/mL)	0.75	0.67-0.83	108.3	73.8	71.2	69.1	75.7
CIV (ng/mL)	0.74	0.66-0.82	110.5	74.1	70.5	68.3	75.9
PIIINP (ng/mL)	0.69	0.61-0.77	12.1	68.9	66.3	64.2	70.8
FIB-4	0.71	0.63-0.79	4.38	70.2	67.9	65.8	72.1
MELD	0.65	0.57-0.73	17.2	66.5	63.4	61.3	68.4
Joint Prediction Model	0.86	0.78-0.93	154.8	80.3	78.5	76.2	82.1

Note: EGV: esophageal and gastric varices; HA: hyaluronic acid; LN: laminin; CIV: type IV collagen; PIIINP: type III procollagen N-terminal peptide; FIB-4: liver fibrosis 4 factor index; MELD: model for end-stage liver disease; AUC: area under the curve; CI: confidence interval; PPV: positive predictive value; NPV: negative predictive value.

soidal endothelial cell basement membrane; their abnormal deposition exacerbates sinusoidal capillaryization, further elevating portal vein pressure. The FIB-4 index integrates age, liver function indicators, and platelet count, reflecting both the severity of fibrosis and the indirect impact of portal hypertension on hematopoietic function. For patients with cirrhosis but without esophagogastric varices (Non-EGV), the mean FIB-4 index was 1.89 ± 0.37, which was below the threshold of 2.67 for advanced liver fibrosis (F3-F4). This was attributed to the absence of varices, indicating relatively mild portal hypertension and that the progression of fibrosis-related indicators had not been further exacerbated by severe hemodynamic disturbances. This observation aligns with the clinical correlation between the FIB-4 index and the severity of portal hypertension. Meanwhile, the MELD score - a classic indicator of liver reserve capacity - signals severe hepatic impairment when elevated, closely correlating with portal hypertension severity and jointly contributing to EGV progression [19-22]. HA, as a sensitive indicator of liver fibrotic activity, was shown to significantly increase the risk of EGV severity progression by 62.3% (OR=1.623, *P*=0.008) for every 50 ng/mL increase. This aligns with the pathological mechanism whereby HA reflects hepatic sinusoidal endothelial injury and exacerbates portal hypertension. For every 50 ng/mL increase in LN and CIV, the risk of EGV severity progression was increased by 84.5% and 70.2%, respectively (both *P*<0.01). Their abnormal deposition can aggravate sinusoidal capillarization, further elevating portal pressure. For every 1-unit increase in FIB-4 and every 5-point increase in MELD score, the risk was increased by 79.6% and 78.9%, respectively (both *P*<0.05), reflecting the synergistic impact of the comprehensive degree of fibrosis and hepatic reserve function on EGV progression.

The combined prediction model developed based on the aforementioned independent risk factors achieved an AUC of 0.89 in predicting the severity of EGV, which was significantly higher than that of any single indicator [23]. Notably, the diagnostic performance of the integrated model in this study (internal cohort AUC=0.89, external validation AUC=0.86) was consistent with and complementary to findings from recent related research. Zhang et al. [24] constructed a nomogram model based on platelet count (PLT), D-dimer (D-D), and spleen diameter (SD), achieving an AUC of 0.961. Its key advantage lay in the inclusion of hematologic and imaging indicators related to portal hypertension, aligning with the modeling approach of this study to integrate multi-dimensional indicators for enhanced predictive efficacy. Compared to single indicators, the combined model incorporated multi-dimensional information such as liver fibrosis stage and hepatic reserve function, more comprehensively reflecting the pathophysiological basis of EGV development and effectively compensating for the limitations of single-indicator assessment [25-27]. This study visualized the complex regression model through a nomogram, enabling clinicians to quickly obtain predicted probabilities for different EGV severity levels via simple score accumulation. This method was operationally convenient, intuitive, and significantly enhanced the model's clinical utility. Decision curve analysis further confirmed that, across a wide range of risk thresholds, the model offered superior clinical net benefit compared to traditional intervention strategies. It effectively identified high-risk patients requiring intervention while avoiding overtreatment or missed diagnoses [28]. The application of SHAP analysis endowed the model with good interpretability, clarifying the predictive weight and direction of each indicator: FIB-4 exhibited the strongest negative contribution to "high EGV risk", where lower levels indicated higher EGV risk, consistent with thrombocytopenia being a key manifestation of portal hypertension; CIV showed the most significant positive contribution, with its elevation directly reflecting sinusoidal structural damage and exacerbating venous outflow obstruction. This quantitative feature interpretation not only helped clinicians understand the model's prediction logic but also provided data support for research into EGV pathogenesis, making the model valuable for both clinical application and scientific research. External validation further confirmed the clinical value of this combined model: compared to the internal cohort AUC of 0.89, the external cohort AUC slightly decreased to 0.86 but maintained high diagnostic accuracy, suggesting the model was not overfitted to the internal data and possessed good cross-population adaptability. This stability was attributed to consistent inclusion/exclusion criteria and uniform testing methods across both cohorts, reducing interference from technical and population selection biases [29].

Through multi-dimensional screening and incremental value verification, this study ultimately identified "HA+LN+CIV+PIIINP+FIB-4+MELD" as the combined predictive indicators. Stepwise integration and analysis of different indicator combinations revealed that the AUCs of single liver fibrosis serum markers (HA, LN, CIV, PIIINP) ranged only between 0.72 and 0.78, indicating limited diagnostic efficacy. After adding FIB-4, the baseline model AUC increased from 0.768 to 0.794, benefiting from FIB-4's integration of age, liver function, and platelet count information, which supplemented systemic metabolic and hematopoietic involvement related to liver fibrosis, aligning more closely with the pathophysiological mechanism of EGV development. Further inclusion of the MELD score significantly increased the AUC to 0.89, as it directly reflected hepatic reserve function. The degree of liver function impairment is closely related to portal hypertension progression, and together, these comprehensively covered key factors influencing EGV severity [30]. Although AAR was initially considered a candidate predictor, data analysis showed no statistical difference across EGV severity groups and no clear association with EGV severity; thus, it was excluded from the final model to avoid irrelevant indicators affecting the reliability of the conclusions. This screening process demonstrated that the final combined model possessed both pathophysiological rationality and statistical validation support. Incremental value analysis also confirmed the necessity of each included indicator, excluding irrelevant confounding factors.

This study had certain limitations: its single-center retrospective design and limited sample size may have introduced selection bias; the exclusion of imaging indicators such as liver stiffness and spleen diameter may leave room for further improvement in model performance; and the lack of long-term follow-up data prevented validation of the model's predictive value for EGV rupture and bleeding. Future research could involve multi-center, large-sample prospective studies, integrate multi-dimensional indicators to optimize the model, and validate its application in bleeding risk prediction through long-term follow-up, thereby providing more reliable evidence-based medical support for the precise management of cirrhotic EGV.

Conclusion

The study found that the combined predictive model comprising HA+LN+CIV+PIIINP+FIB-4+MELD achieved the highest accuracy in assessing the severity of esophageal and gastric varices (EGV) in patients with liver cirrhosis. The internal cohort validation yielded an area under the curve (AUC) of 0.89 (95% confidence interval: 0.84-0.94), with a sensitivity of 83.6% and a specificity of 81.2%. The external cohort validation demonstrated an AUC of 0.86 (95% confidence interval: 0.78-0.93), significantly surpassing the diagnostic performance of any single indicator. This combined model provided a reliable non-invasive assessment tool for clinical practice. However, as this study was a single-center retrospective analysis with a limited sample size, potential influences from the duration of hepatitis infection and comorbid conditions could not be fully excluded. Future research involving larger sample sizes and multi-center prospective studies could further enhance the accuracy and generalizability of the findings.

Disclosure of conflict of interest

None.

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References

[1] Almomani A, Kumar P, Onwuzo S, Boustany A, Krishtopaytis E, Hitawala A, Alshaikh D, Albakri A, Hussein L, Hussein E and Asaad I. Epidemiology and prevalence of lean nonalcoholic fatty liver disease and associated cirrhosis, hepatocellular carcinoma, and cardiovascular outcomes in the United States: a population-based study and review of literature. J Gastroenterol Hepatol 2023; 38: 269-273.

[2] Zhang YF, Qiao W, Zhuang J, Feng H, Zhang Z and Zhang Y. Association of ultra-processed food intake with severe non-alcoholic fatty liver disease: a prospective study of 143073 UK Biobank participants. J Nutr Health Aging 2024; 28: 100352.

[3] Tonon M and Piano S. Cirrhosis and portal hypertension: how do we deal with ascites and its consequences. Med Clin North Am 2023; 107: 505-516.

[4] Songtanin B, Kahathuduwa C and Nugent K. Esophageal stent in acute refractory variceal bleeding: a systematic review and a meta-analysis. J Clin Med 2024; 13: 357.

[5] Liang Z, Li L, Cao L, Liu J and Liu J. Analyses on clinical efficacy of TIPS in the treatment of cirrhotic portal hypertension and relevant influencing factors. Cell Mol Biol (Noisy-le-grand) 2022; 68: 129-134.

[6] Feng CW, Kang LL and Zhang HD. Prediction of severe esophageal varices in patients with cirrhosis based on Levitt's CO breath test: a proof of concept study. J Clin Gastroenterol 2023; 57: 835-840.

[7] Chen Q, Mei L, Zhong R, Han P, Wen J, Han X, Zhai L, Zhao L and Li J. Serum liver fibrosis markers predict hepatic decompensation in compensated cirrhosis. BMC Gastroenterol 2023; 23: 317.

[8] Plevris N, Sinha R, Hay AW, McDonald N, Plevris JN and Hayes PC. Index serum hyaluronic acid independently and accurately predicts mortality in patients with liver disease. Aliment Pharmacol Ther 2018; 48: 423-430.

[9] Emenena I, Emenena B, Kweki AG, Aiwuyo HO, Osarenkhoe JO, Iloeje UN, Ilerhunmwuwa N, Torere BE, Akinti O, Akere A and Casimir OE. Model for end stage liver disease (MELD) score: a tool for prognosis and prediction of mortality in patients with decompensated liver cirrhosis. Cureus 2023; 15: e39267.

[10] Huo RR, Pan LX, Wu PS, Liang XM, You XM, Ma L and Zhong JH. Prognostic value of aspartate aminotransferase/alanine aminotransferase ratio in hepatocellular carcinoma after hepatectomy. BJS Open 2024; 8: zrad155.

[11] Niu A and Qi T. Diagnostic significance of serum type IV collagen (IVC) combined with aspartate aminotransferase (AST)/alanine aminotransferase (ALT) ratio in liver fibrosis. Ann Transl Med 2022; 10: 1310.

[12] Huang DQ, Terrault NA, Tacke F, Gluud LL, Arrese M, Bugianesi E and Loomba R. Global epidemiology of cirrhosis - aetiology, trends and predictions. Nat Rev Gastroenterol Hepatol 2023; 20: 388-398.

[13] Mazumder NR and Fontana RJ. MELD 3.0 in advanced chronic liver disease. Annu Rev Med 2024; 75: 233-245.

[14] Horvatits T, Mahmud N, Serper M, Seiz O, Reher D, Drolz A, Sarnast N, Gu W, Erasmus HP, Allo G, Ferstl P, Wittmann S, Piecha F, Groth S, Zeuzem S, Schramm C, Huber S, Rösch T, Lohse AW, Trebicka J, Ogola G, Asrani SK and Kluwe J. MELD-lactate predicts poor outcome in variceal bleeding in cirrhosis. Dig Dis Sci 2023; 68: 1042-1050.

[15] Song J, Wang X, Yan Y, Xiang T and Luo X. MELD 3.0 score for predicting survival in patients with cirrhosis after transjugular intrahepatic portosystemic shunt creation. Dig Dis Sci 2023; 68: 3185-3192.

[16] Duan X, He X, Yan H, Li H, Wang J, Guo S, Zha Z, Zhang Q, Bai Y, Zhang J, Tang J and Kong D. Analysis of complications and risk factors other than bleeding before and after endoscopic treatment of esophagogastric variceal bleeding in patients with liver cirrhosis. Can J Gastroenterol Hepatol 2023; 2023: 7556408.

[17] Kim JW, Kim JH, Choe WH, Kwon SY and Yoo BC. MELD-GRAIL-Na is a better predictor of mortality than MELD in Korean patients with cirrhosis. Medicina (Kaunas) 2023; 59: 592.

[18] Kayadibi H, Köker İH, Gucin Z, Şentürk H, Merzifonlu SC and İnce AT. Comparison of the

optimized direct spectrophotometric serum prolidase enzyme activity assay method with the currently used spectrophotometric assay methods and liver fibrosis indexes to distinguish the early stages of liver fibrosis in patients with chronic hepatitis B infection. Lab Med 2023; 54: 652-658.
[19] Özgüler M, Durak S, Solmaz ÖA, Eser Karlıdağ G, Gündağ Ö, Kırık Y, Tanır B and Selim Kara S. The use of serum scoring systems in predicting liver fibrosis caused by chronic hepatitis B: a retrospective case-control study. Medicina (Kaunas) 2025; 61: 1490.
[20] Yang K, Ying P and Sun B. Interleukin-34 is more suitable than macrophage colony-stimulating factor for predicting liver significant fibrosis in patients with chronic hepatitis B. Scand J Gastroenterol 2024; 59: 78-84.
[21] Zhou L, Lin Y, Pan C, Han X, Huang Z, Sun F, Zhou R and Lin C. Noninvasive diagnostic value of indocyanine green retention test in patients with esophagogastric varices in liver cirrhosis. Eur J Gastroenterol Hepatol 2022; 34: 1081-1089.
[22] Broussard KA and Rockey DC. Bleeding ectopic varices: clinical presentation, natural history, and outcomes. J Investig Med 2022; 70: 1280-1284.
[23] Xiao L, Zhao H, Liu S, Dong W, Gao Y, Wang L, Huang B and Li Z. Staging liver fibrosis: comparison of radiomics model and fusion model based on multiparametric MRI in patients with chronic liver disease. Abdom Radiol (NY) 2024; 49: 1165-1174.
[24] Zhang D, Deng J, Guo X, Zheng Y and Xu X. Nomogram model for predicting esophsagogastric varices in hepatocellular carcinoma with cirrhosis. Eur J Gastroenterol Hepatol 2023; 35: 342-348.
[25] Yang L, Zhang Y, Hong X, Zhang K, Liu B, Zhang P, Tang Q, Yu J, Jin XZ, Jin XZ, Zhang N, Targher G, Byrne CD, Zhang Z, Zheng MH and Zhang J. Serum dithiothreitol-oxidizing capacity (DOC) is a promising biomarker for excluding significant liver fibrosis: a proof-of-concept study. BMC Med 2024; 22: 278.
[26] Su CW, Fang KC, Lee RC, Liu CA, Chen PH, Lee PC, Kao WY, Huang YH, Huo TI, Hou MC, Lin HC and Wu JC. Association between esophagogastric varices in hepatocellular carcinoma and poor prognosis after transarterial chemoembolization: a propensity score matching analysis. J Formos Med Assoc 2020; 119: 610-620.
[27] Iwai S, Akahane T, Takaya H, Kubo T, Tomooka F, Shibamoto A, Suzuki J, Tsuji Y, Fujinaga Y, Nishimura N, Kitagawa K, Kaji K, Kawaratani H, Namisaki T, Matsumoto M and Yoshiji H. Ratio of von Willebrand factor to ADAMTS13 is a useful predictor of esophagogastric varices progression after sustained virologic response in patients with hepatitis C virus-related liver cirrhosis. Hepatol Res 2024; 54: 1116-1127.
[28] Tani T, Sato K, Sakamoto K, Ito E, Nishiyama M, Urakawa H and Yoshimitsu K. Importance of extracellular volume fraction of the spleen as a predictive biomarker for high-risk esophagogastric varices in patients with chronic liver diseases: a preliminary report. Eur J Radiol 2021; 143: 109924.
[29] Feng SY, Ding ZR, Cheng J and Tu HB. Noninvasive prediction of esophagogastric varices in hepatitis B: an extreme gradient boosting model based on ultrasound and serology. World J Gastroenterol 2025; 31: 104697.
[30] Yardeni D, Shiloh A, Lipnizkiy I, Nevo-Shor A, Abufreha N, Munteanu D, Novack V and Etzion O. MELD-Na score may underestimate disease severity and risk of death in patients with metabolic dysfunction-associated steatotic liver disease (MASLD). Sci Rep 2023; 13: 22113.