BMC Gastroenterology

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Ascites complications risk factors of decompensated cirrhosis patients: logistic regression and prediction model

Xiaolong Zheng[1] and Wei Wei[1*]

Abstract

Objective The study mainly aim at exploring the ascites risk factors among decompensated cirrhosis patients via constructing the prediction model of ascites incidence.

Methods Here, we recruited 148 decompensated cirrhosis patients for analysis, their laboratory tests and complications recorded. T-test, chi-square test, single-factor logistic regression, multi-factor logistic regression, and nomogram model were used to investigate the ascites occurred factors in decompensated cirrhosis patients with ascites. To validate the data analysis results, we applied the receiver operating characteristic (ROC) curve, calibration curve, and decision curve analysis (DCA) to evaluate the discrimination, calibration, and clinical usefulness of the prediction model, respectively.

Results Serum creatinine levels were higher in the cirrhotic ascites group than in the non-ascites group. The ascites group had lower albumin and serum sodium levels, as well as a lower incidence of variceal bleeding and varicose veins compared to the non-ascites group.

Conclusion Varicose veins, variceal bleeding, and serum sodium levels are significant factors contributing to ascites development in cirrhosis. Furthermore, decreased serum albumin and elevated creatinine levels are important indicators of poor prognosis. Nomograms can improve clinicians' informed decision-making for patients with decompensated cirrhosis, ultimately reducing ascites risk.

Keywords Decompensation cirrhosis, Serum albumin, Ascites, Prediction model

Introduction

Cirrhosis is characterized by extensive liver damage caused by various factors. Cirrhosis, the advanced stage of chronic liver disease, is characterized by the formation of dense fibrous tissue-covered nodules as a response to liver cell damage. As cirrhosis progresses to the decompensated stage, patients exhibit symptoms of declining liver function and abnormally increased portal vein pressure. Cirrhotic ascites, the abdominal fluid accumulation, clearly indicates decompensated cirrhosis. Ascites develops due to an imbalance between intra-abdominal fluid production and absorption. Factors contributing to ascites include decreased plasma albumin, portal hypertension, impaired inactivation of aldosterone and antidiuretic hormone, reduced lymph excretion, and poor renal perfusion. Approximately 58% of patients with compensated cirrhosis develop cirrhotic ascites within 10 years of diagnosis [1]. Once hepatic

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ascites (abdominal fluid volume > 200 mL) develops, the 1-year mortality is approximately 15% [2]. Cirrhosis accounts for 2.4% of annual global deaths [3], with approximately 10.6 million people worldwide having decompensated cirrhosis [4]. In the United States, the mean length of stay (LOS) and total cost of care (COC) for patients with cirrhosis and ascites are 5.52 days and $42,221, respectively [5]. The high prevalence of cirrhosis ascites and associated medical costs have increased the global burden, leading to substantial economic strain on families. Ascites can be diagnosed through physical examination, abdominal ultrasonography, computed tomography, and diagnostic paracentesis. Different treatment strategies are employed for patients with varying grades of ascites. Generally, interventions such as diuretics, sodium and water restriction, repeated paracentesis, and albumin supplementation can alleviate symptoms of ascites and decrease the risk of recurrence and mortality. For patients with refractory ascites, invasive treatments, including transjugular intrahepatic portosystemic shunt (TIPS) and liver transplantation, may be considered. Nonetheless, the prognosis for these patients remains poor.Therefore, early prediction of ascites is crucial for improving survival [6]. Current research on ascites mainly focuses on diagnosis, treatment, and risk factors. These risk factors may have interdependent effects, leading to conflicting results across studies. Notably, the Asia-Pacific region accounted for 54.3% of global liver cirrhosis deaths in 2015 [7]. Ascites is a crucial indicator of liver cirrhosis progression. Early, targeted ascites prevention can reduce cirrhosis-related harm. Variceal and ascites development in decompensated cirrhosis patients significantly impacts survival. Despite being a critical sign of decompensated cirrhosis, ascites is often overlooked, emphasizing the importance of identifying and understanding ascites risk factors for effective monitoring and prediction. Developing a predictive model for ascites in decompensated liver cirrhosis is crucial. Nomograms, as efficient and reliable prediction tools used by clinicians, hold significant value. This retrospective study, conducted from July 2021 to November 2023, aimed to explore the impact of age, gender, albumin, alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, total bilirubin, serum creatinine, total cholesterol, serum sodium, prothrombin time, international normalized ratio, white blood cell count, hemoglobin, neutrophil count, complications (variceal bleeding, hepatic encephalopathy, bacterial infection, and hepatorenal syndrome), MELD and Child-Pugh classification on patients with decompensated liver cirrhosis. The study sought to establish a new model for early ascites prediction in cirrhosis, facilitating timely intervention and improving prognosis.

Methods

Patients

This retrospective study, conducted at the Second Affiliated Hospital of Zhejiang University School of Medicine, collected medical records of 148 inpatients diagnosed with decompensated cirrhosis on admission between July 2021 and November 2023. The data and diagnosis were aligned with the European Society of Liver Diseases Clinical Practice Guidelines for the Management of Patients with Decompensated Cirrhosis [8]. Diagnosis was based on liver cirrhosis and complications of portal hypertension, including ascites, variceal bleeding, hepatic encephalopathy, and related complications such as sepsis or hepatorenal syndrome. Patient diagnosis was established using past medical history, clinical manifestations, laboratory examinations, imaging examinations, or histopathology. All patients underwent abdominal contrast-enhanced CT examination, including those with creatinine levels ≥ 120 μmol/L requiring emergency investigation. Patients with signs of varices underwent endoscopy to diagnose esophageal and gastric varices or variceal bleeding. Ascites was diagnosed when intraperitoneal fluid volume was ≥ 200 ml on ultrasonography.

Inclusion criteria for this study were: (1) Age between 18 and 95 years; (2) Adherence to the European Society of Liver Diseases' 'Clinical Practice Guidelines for the Management of Patients with Decompensated Cirrhosis' (3) Provision of signed informed consent. Exclusion criteria were: (1) Acute or subacute liver failure; (2) Portal vein thrombosis; (3) Liver or other malignancies, severe cardiopulmonary, or renal diseases(Patients with New York Heart Association (NYHA) class III-IV or chronic obstructive pulmonary disease (GOLD stage 3–4).(4) Pregnancy; (5) Terminal illness; (6) Liver transplantation; (7) Use of glucocorticoids or immunosuppressants; (8) Incomplete medical records; and (9) HIV infection.

Clinical data collection

Clinical data and laboratory indicators were collected, including age, gender, albumin(Alb), Alanine aminotransferase(ALT), aspartate aminotransferase(AST), Alkaline phosphatase(ALP), total bilirubin(TBIL), serum creatinine(SCr), total cholesterol(total cholesterol), serum sodium(Na+), prothrombin time(PT), international normalized ratio(INR), white blood cell count(WBC), hemoglobin(Hb), Absolute neutrophil count(NEUT), variceal bleeding, hepatic encephalopathy(HE), bacterial infection(BI), hepatorenal syndrome(HRS), and ascites. Child-Pugh classification was used to determine liver disease severity based on the total score calculated from hepatic encephalopathy, ascites, TBIL, ALB, and prothrombin time. Scores of 5–6, 7–9, and 10–15 indicated grades A, B, and C, respectively, with higher scores indicating poorer liver

function and functional reserve. MELD score based on creatinine, INR and total bilirubin: score > 18 points, high risk; score 15–18 points, intermediate risk; score ≤ 14 points, low risk.Variceal bleeding was diagnosed through emergency gastroscopy, while the diagnosis of ascites was independently evaluated by two radiologists using ultrasonography, and patients belonging to Grade 1 ascites(15 cases) were identified(ascites can only be detected by ultrasound examination, and the depth of ascites under B-ultrasound is less than 3 cm).All examinations were performed in the hospital's laboratory department, and cases were collected through the electronic medical record system. Patients were divided into ascites and no-ascites groups based on the presence or absence of ascites at discharge.

Statement of ethics

The Ethics Committee of the Second Affiliated Hospital of Zhejiang University School of Medicine approved this study (I202421), and informed consent was obtained from each patient. The study protocol adhered to the ethical guidelines of the latest version of the Declaration of Helsinki (2024). This research did not receive any specific grants from public, commercial, or not-for-profit funding agencies.

Data analysis

Statistical analysis and chart generation were performed using Rstudio (R Core Team, 2023, Vienna, Austria). Measurement data were presented as mean ± standard deviation (x ± s), and component differences were analyzed using t-tests. For categorical data, chi-square tests were used to assess component differences. Count data were expressed as percentages, and group differences were analyzed using the chi-square test. Single-factor and multi-factor logistic regression were employed to examine risk factors for ascites in patients with decompensated liver cirrhosis. Variables with a P value < 0.05 in univariate analysis were included in the multivariate analysis, Variables were eliminated based on the P value, and a ROC curve was plotted to calculate the area under the curve (AUC). The optimal critical value was determined based on the ROC curve's sensitivity and specificity. A nomogram was constructed to predict the incidence of ascites in decompensated cirrhosis using the regression model. The model's predictive ability was evaluated through calibration plots and decision curve analysis (Fig. 1),Bootstrap resampling was performed 1000 times to verify the stability of the calibration curve. A P value less than 0.05 was considered statistically significant.

Results

Patient characteristics and group comparisons

A total of 148 patients with decompensated cirrhosis were included in this study. The etiologies of cirrhosis were as follows: hepatitis B ($n = 60$), hepatitis C ($n = 3$), non-alcoholic fatty liver disease ($n = 3$), alcohol ($n = 27$), schistosomiasis ($n = 8$), autoimmune ($n = 7$), genetic metabolic ($n = 1$), and primary biliary ($n = 10$). Cryptogenic cirrhosis was diagnosed after ruling out possible causes such as alcohol, hepatotropic viruses, autoimmune liver disease, drugs, and genetic metabolic disorders through a thorough evaluation of medical history, laboratory tests, and histology. Patients were divided into two groups based on the presence of ascites: the ascites group ($n = 103$; 71 males [68.93%], 32 females [31.07%]), Among the 103 patients with ascites, 13 (12.62%) developed HRS, and 15 had grade 1 ascites.and the non-ascites group ($n = 45$; 28 males [62.22%], 17 females [37.78%]). Of note, 83 patients were admitted due to acute decompensation, while 65 were admitted for non-acute reasons. Among these, 56 patients initially presented without ascites but were diagnosed with ascites upon discharge [9]; notably, 49 of these patients had a Child-Pugh grade of B or higher. Furthermore, 28 patients had a history of prior decompensation events, such as variceal bleeding or hepatic encephalopathy. At the time of admission, 18 patients exhibited variceal bleeding, 6 presented with hepatic encephalopathy, and another 6 were diagnosed with hepatorenal syndrome (HRS). Of the 45 patients discharged without ascites, 18 had a history of prior decompensation events.

In the NAG group, the Child-Pugh classification was as follows: grade A, 29 cases (64.4%); grade B, 11 cases (24.4%); and grade C, 5 cases (11.1%). In contrast, the ascites group (AG) had 11 cases (10.7%) in grade A, 74 cases (71.8%) in grade B, and 18 cases (17.5%) in grade C. The proportion of Child-Pugh grades B and C was significantly higher in the AG compared to the NAG ($P < 0.001$). This trend is also reflected in the MELD score, where the AG group exhibited a higher mean score of 9.40 (± 5.43) compared to the NAG group, which had a mean score of 6.58 (± 5.52). The difference between the two groups was statistically significant ($P = 0.004$).(Table 1).

The non-ascites group had significantly higher levels of albumin (Alb), lower serum creatinine (SCr), and higher serum sodium (Na+) compared to the ascites group ($P < 0.001$, $p = 0.002$, and $P = 0.003$, respectively). Moreover, the incidence of variceal veins and hepatorenal syndrome was significantly lower in the non-ascites group than in the ascites group ($P < 0.05$) (Table 1).

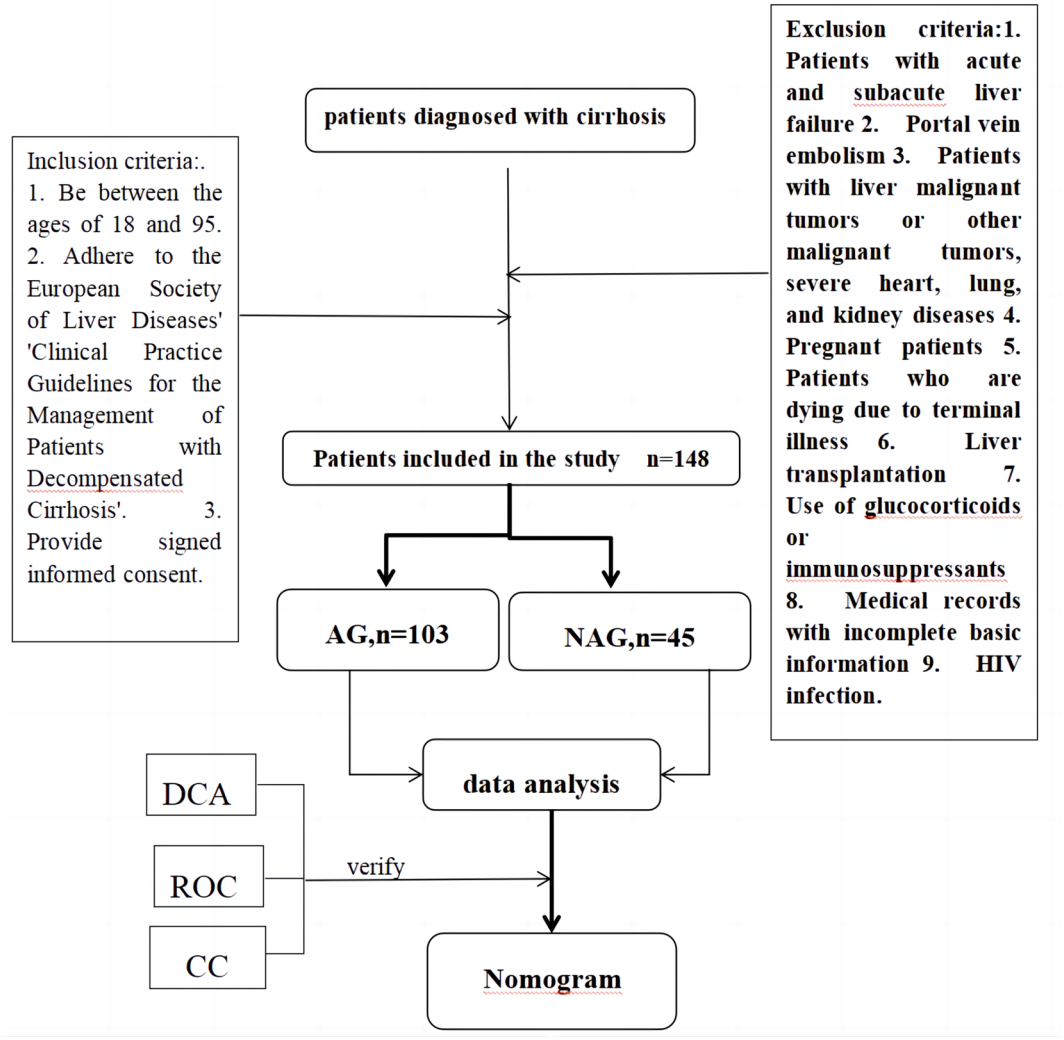

Fig. 1 The research flow chart

Risk factors for ascites development and nomogram construction

This study aimed to identify risk factors for ascites in patients with decompensated cirrhosis using univariate and multivariate logistic regression analyses. A nomogram was constructed based on the dependent variable of ascites development, along with clinical blood tests and manifestations. The influencing factors, presented in Table 2, were further analyzed using univariate and multivariate logistic regression. Multivariate logistic regression analysis revealed that serum creatinine (SCr) (OR = 1.02, $P = 0.034$) was an independent risk factor, while albumin (OR = 0.88; $P < 0.001$) was a protective factor (Table 2). To facilitate clinical research and predict the probability of ascites, a visual nomogram incorporating variceal veins, variceal bleeding, albumin, SCr, and serum sodium (Na+) was constructed based on the regression model (Fig. 2).

Nomogram evaluation and model performance

The nomogram for predicting the probability of ascites in patients with decompensated cirrhosis was evaluated. First, the receiver operating characteristic (ROC) curve was plotted based on the prediction model. The area under the curve (AUC) was 0.795, indicating good discrimination. The optimal cut-off value was determined to be 0.653 (sensitivity: 0.745, specificity: 0.750), suggesting that patients with decompensated cirrhosis are at risk of developing ascites when the value exceeds 0.653. The AUC of the ROC curve excluding patients with grade 1 ascites was 0.812, and the optimal cut-off value was determined to be 0.647 (sensitivity: 0.807, specificity: 0.756)(Fig. 3). The bootstrap method was repeated 1,000 times, and the actual prediction line of the calibration curve closely aligned with the ideal line. After verification using patient data from non-grade 1 ascites, the calibration curve continued to demonstrate a high degree of fit

Table 1 Characteristic of NAG group and AG group

All patients				
	NAG(*n* = 45)	**AG(*n* = 103)**	**X^2**	***P***
Child-Pugh			46.563	< 0.001
A	29(64.4%)	11(10.7%)		
B	11(24.4%)	74(71.8%)		
C	5(11.1%)	18(17.5%)		
MELD				
	6.58 ± 5.52	9.40 ± 5.43		0.004
				0.075
low risk	43 (95.6%)	88 (85.4%)		
intermediate risk	0 (0.0)	11 (10.7%)		
high risk	2 (4.4%)	4 (3.9%)		
Characteristic	**Overall**(*n* = **148**)	**NAG** (*n* = **45**)	**AG** (*n* = **103**)	**P**
age, years				0.729
< 60	61 (41.22%)	20 (44.44%)	41 (39.81%)	
≥ 60	87 (58.78%)	25 (55.56%)	62 (60.19%)	
Gender				0.543
Male	99 (66.89%)	28 (62.22%)	71 (68.93%)	
Female	49 (33.11%)	17 (37.78%)	32 (31.07%)	
Varicosity				0.005
No	37 (25.00%)	4 (8.89%)	33 (32.04%)	
Yes	111 (75.00%)	41 (91.11%)	70 (67.96%)	
Variceal bleeding				0.069
No	84 (56.76%)	20 (44.44%)	64 (62.14%)	
Yes	64 (43.24%)	25 (55.56%)	39 (37.86%)	
HE				1
No	126 (85.14%)	38 (84.44%)	88 (85.44%)	
Yes	22 (14.86%)	7 (15.56%)	15 (14.56%)	
BI				0.314
No	144 (97.30%)	45 (100.00%)	99 (96.12%)	
Yes	4 (2.70%)	0 (0.00%)	4 (3.88%)	
HRS				0.01
No	135 (91.22%)	45 (100.00%)	90 (87.38%)	
Yes	13 (8.78%)	0 (0.00%)	13 (12.62%)	
Alb(g/L)	31.32 ± 5.57	33.97 ± 5.90	30.17 ± 5.03	< 0.001
ALT(U/L)	35.93 ± 55.09	32.40 ± 50.01	37.47 ± 57.33	0.589
AST(U/L)	59.63 ± 94.39	58.29 ± 105.96	60.21 ± 89.42	0.916
ALP(U/L)	132.31 ± 114.96	114.60 ± 53.03	140.67 ± 134.16	0.111
TBil(umol/L)	33.34 ± 39.56	28.93 ± 24.97	35.26 ± 44.43	0.272
SCr(umol/L)	85.56 ± 53.43	70.88 ± 19.60	92.04 ± 61.82	0.002
TC(mol/L)	3.59 ± 1.93	3.70 ± 1.04	3.54 ± 2.17	0.589
Na(mol/L)	139.17 ± 3.47	140.37 ± 2.98	138.65 ± 3.55	0.003
PT(s)	16.06 ± 2.76	15.70 ± 2.83	16.22 ± 2.73	0.311
INR	1.33 ± 0.28	1.28 ± 0.31	1.35 ± 0.27	0.185
WBC(10^9/L)	4.27 ± 2.33	4.15 ± 2.13	4.32 ± 2.43	0.661
Hb(g/L)	94.24 ± 27.36	95.95 ± 29.34	93.49 ± 26.56	0.632
NEUT(10^9/L)	2.84 ± 1.93	2.56 ± 1.60	2.96 ± 2.05	0.202
Patients with grade 1 ascites removed				
		NAG(*n* = **45**)	**AG**(*n* = **88**)	**P**
Child-Pugh				< 0.001
A		29(64.4%)	9(10.23%)	
B		11(24.4%)	63(71.59%)	
C		5(11.1%)	16(18.18%)	
Characteristic				

Table 1 (continued)

All patients			
	NAG($n=45$)	AG($n=103$)	X^2	P
age, years			0.740
< 60	20 (44.44%)	35(39.77%)	
≥ 60	25 (55.56%)	53(60.23%)	
Gender			0.622
Male	28 (62.22%)	60(68.18%)	
Female	17 (37.78%)	28(31.82%)	
Varicosity			0.002
No	4 (8.89%)	31(35.2%)	
Yes	41 (91.11%)	57 (64.8%)	
Variceal bleeding			0.072
No	20 (44.44%)	55(62.5%)	
Yes	25 (55.56%)	33 (37.5)	
HE			1
No	38 (84.44%)	75(85.2%)	
Yes	7 (15.56%)	13 (14.8%)	
BI			0.36
No	45 (100.00%)	84(95.5%)	
Yes	0 (0.00%)	4 (4.5%)	
HRS			0.023
No	45 (100.00%)	76(86.4%)	
Yes	0 (0.00%)	12 (13.6)	
Alb(g/L)	33.97 ± 5.90	30.04 ± 4.70	< 0.001
ALT(U/L)	32.40 ± 50.01	39.47 ± 61.45	0.478
AST(U/L)	58.29 ± 105.96	61.84 ± 93.93	0.850
ALP(U/L)	114.60 ± 53.03	147.51 ± 144.83	0.078
TBil(umol/L)	28.93 ± 24.97	36.28 ± 47.64	0.245
SCr(umol/L)	70.88 ± 19.60	91.32 ± 60.37	0.005
TC(mol/L)	3.70 ± 1.04	3.56 ± 2.34	0.652
Na(mol/L)	140.37 ± 2.98	138.34 ± 3.60	0.001
PT(s)	15.70 ± 2.83	16.30 ± 2.86	0.258
INR	1.28 ± 0.31	1.36 ± 0.28	0.138
WBC(10^9/L)	4.15 ± 2.13	4.40 ± 2.52	0.543
Hb(g/L)	95.95 ± 29.34	93.50 ± 26.21	0.638
NEUT(10^9/L)	2.56 ± 1.60	3.04 ± 2.15	0.149

HE, hepatic encephalopathy; BI, Bacterial infections;HRS, Hepatorenal syndrome;Alb, albumin;ALT, Alanine aminotransferase;AST, aspartate aminotransferase;ALP, Alkaline phosphatase;TBil, total bilirubin;TC, total cholesterol;PT, prothrombin time;INR, international normalized ratio;WBC, White blood cell count;Hb, hemoglobin;NEUT, Absolute neutrophil count;SCr, Serum creatinine;Na, Serum sodium

(Fig. 4). Additionally, the decision curve analysis (Fig. 5) indicated that when the threshold probability exceeded 0.35, the net benefit of using this prediction model was maximized. For patients with overt ascites, a threshold probability of 0.28 could achieve the optimal net benefit.

Discussion

Cirrhosis and ascites are significant global public health challenges. Elucidating the risk factors associated with ascites in decompensated cirrhosis is crucial. Portal hypertension and low albumin levels are recognized as key drivers for ascites development within the medical community. Recent studies have also revealed associations between hepatic encephalopathy [10], alcoholic cirrhosis [11], and decreased lymphocyte count [12] with the occurrence of cirrhotic ascites. However, research on the development of ascites risk prediction models is limited.

In this study, Alb and Na + levels had a more pronounced impact on ascites occurrence in cirrhotic patients, consistent with previous research [13, 14]. Lower Alb and Na + levels contribute to more severe symptoms and higher risk of ascites. Although portal hypertension is the primary factor in ascites [15], severe hyponatremia better predicts patient mortality [16]. Improving Alb levels remains a reliable treatment for decompensated cirrhosis [17], aligning with our conclusions. Higher SCr levels in the ascites group emerged as

Table 2 Univariate and multivariate logistic regression analysis

	Univariate Analysis		Multivariate Analysis	
Characteristic	OR(95% CI)	P	OR(95% CI)	P
age, years				
< 60	Reference		Reference	
≥ 60	1.21 (0.59,2.46)	0.602		
Gender				
male	Reference		Reference	
Female	0.74 (0.36,1.57)	0.432		
Varicosity				
No	Reference		Reference	
Yes	0.22 (0.06;0.59)	0.002	0.28 (0.07,0.97)	0.570
Variceal bleeding				
No	Reference		Reference	
Yes	0.49 (0.24;1.00)	0.050	0.74 (0.30,1.79)	0.510
HE				
No	Reference		Reference	
Yes	0.92 (0.35,2.61)	0.864		
BI				
No	Reference		Reference	
Yes	-			
HRS				
No	Reference		Reference	
Yes	-			
Alb	0.88 (0.82,0.94)	< 0.001	0.88 (0.81,0.94)	< 0.001
ALT	1.00 (0.99,1.01)	0.612		
AST	1.00 (1.00,1.00)	0.909		
ALP	1.00 (1.00,1.01)	0.240		
TBil(umol/L)	1.01 (0.99,1.02)	0.388		
SCr(umol/L)	1.02 (1.00,1.03)	0.025	1.02 (1.00,1.04)	0.034
TC(mol/L)	0.96 (0.79,1.17)	0.687		
Na(mol/L)	0.84 (0.74,0.95)	0.007	0.90 (0.76,1.05)	0.182
PT(s)	1.08 (0.94,1.24)	0.304		
INR	2.80 (0.65,12.0)	0.166		
WBC	1.03 (0.89,1.21)	0.675		
Hb(g/L)	1.00 (0.98,1.01)	0.615		
NEUT	1.13 (0.92,1.39)	0.246		

HE, hepatic encephalopathy; BI, Bacterial infections;HRS, Hepatorenal syndrome;Alb, albumin;ALT, Alanine aminotransferase;AST, aspartate aminotransferase;ALP, Alkaline phosphatase;TBil, total bilirubin;TC, total cholesterol;PT, prothrombin time;INR, international normalized ratio;WBC, White blood cell count;Hb, hemoglobin;NEUT, Absolute neutrophil count;SCr, Serum creatinine;Na, Serum sodium

an independent risk factor for ascites occurrence and can predict 6-month mortality in decompensated cirrhosis [18]. Further verification is required through larger, multi-center studies.

The ascites group(AG) had a higher probability of variceal veins and bleeding compared to the non-ascites group(NAG), with no statistical difference in HE and HRS. This suggests a parallel or inverse relationship between ascites and systemic complications. Recent studies found hepatorenal syndrome common in advanced cirrhosis [19], with SCr linked to renal damage. Lower Na + in cirrhotic ascites patients is associated with higher HE incidence [20]. These contradictions and connections may be due to sample size, research design, and potential physiological mechanisms.

Esophageal and gastric varices and bleeding are significant complications in decompensated cirrhosis, caused by portal hypertension from liver scarring. When hepatic venous pressure gradient(HVPG) exceeds 20 mm Hg, bleeding risk increases [21, 22], highlighting their close relationship. Ascites is also a major complication of portal hypertension [15]. Previous studies confirmed this association: worsening portal pressure increases nitric oxide production, maintaining hyperdynamic circulation [23] and increasing esophageal variceal risk. Nitric oxide decreases sGC activation, and sGC activators improve hyperdynamic circulation in portal hypertensive mice [24]. Increased nitric oxide decreases SVR, stimulating baroreceptors, activating RAAS and SNS, and causing diuretic hormone resistance, leading to increased renal sodium and water reabsorption and ascites [25]. Surprisingly, our study found decompensated cirrhotic patients with varices or bleeding less likely to develop ascites (ORs 0.22 and 0.49). When ascites develops, variceal veins and bleeding probability is lower than in non-ascites patients. This may be due to sample size, limited population, or unnoticed variables. Recent studies showed increased Mucosal Associated Invariant T(MAIT cells) in ascites and decreased in peripheral circulation [26]. This indicates that the quantity and function of MAIT cells are associated with the progression of liver cirrhosis. The accumulation of MAIT cells in the peritoneal cavity may exacerbate the disorder of the peritoneal microenvironment through cytokine secretion. Additionally, MAIT cells regulate nitric oxide metabolism in liver sinusoidal endothelial cells, thereby influencing portal hypertension and systemic vasodilation. Decreased immune cells and their secreted factors may make veins less susceptible to varices. Portal hypertension causes blood reflux, filling collateral veins, decreasing portal pressure, and reducing ascites, providing another explanation.

Creatinine, a muscle metabolism byproduct, is released into the bloodstream and serves as a key marker for renal function. Adebayo et al. found 50% of ascites patients have renal impairment, with type 1 hepatorenal syndrome most significant [27]. Cirrhotic ascites patients are at increased risk of acute renal failure [28]. We found cirrhotic patients with higher creatinine 1.02 times more likely to develop ascites. Creatinine has been used to determine acute liver failure and predict ascites severity [29]. Incorporating creatinine enhanced our prediction model and facilitated clinical judgment.

Serum sodium is crucial for cell function, acid-base balance, osmotic pressure, and blood volume. Previous studies showed Na + as an independent risk factor for HE in decompensated cirrhosis [30]. Bossen et al. found

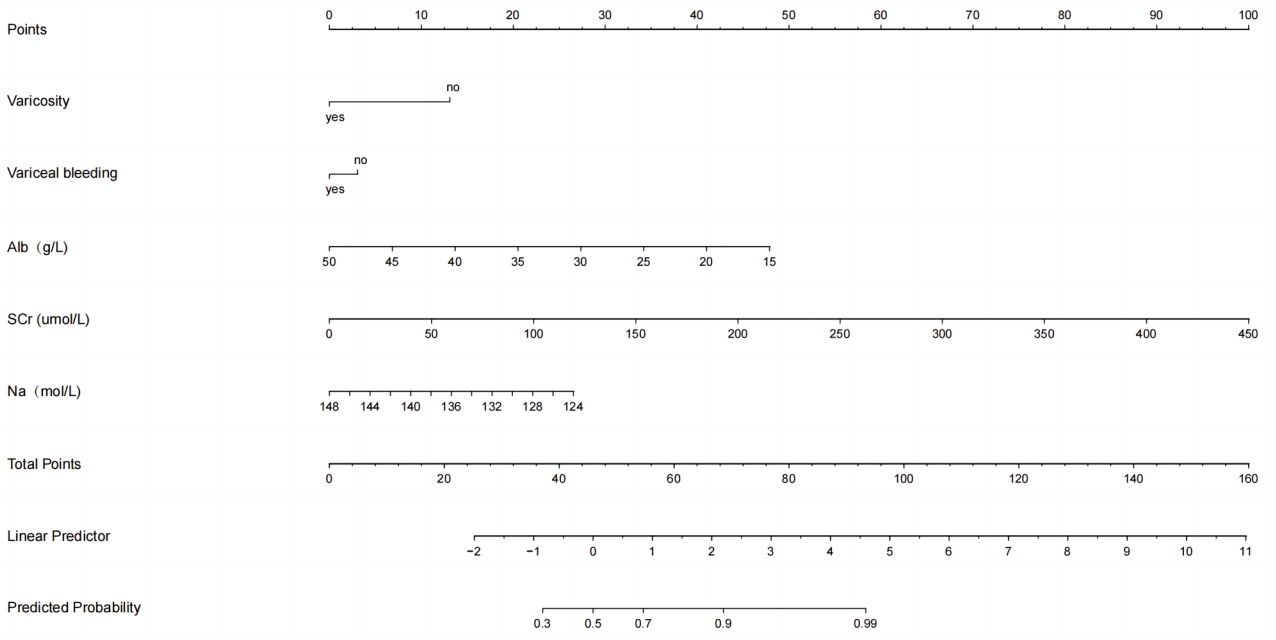

Fig. 2 A nomogram is used to predict the probability of ascites in patients with decompensated cirrhosis. The variable axis of each predictor was established separately, and the patient's information was positioned along each axis. The localization value of each variable axis was oriented vertically upward in relation to the scoring axis to derive a singular score.The scores for the five factors on the variable axis are added together to obtain a total score. By drawing a vertical line downward from the total score and intersecting the probability line segment, the likelihood of ascites in an individual patient can be estimated

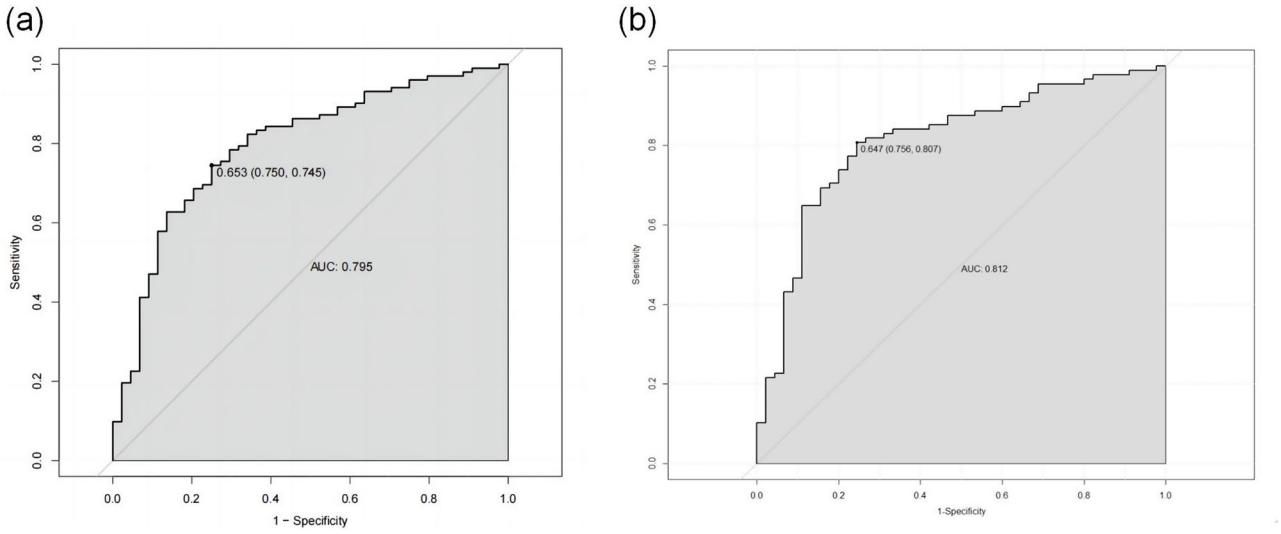

Fig. 3 The ROC curve illustrates the performance of the early diagnosis model for ascites in patients with decompensated cirrhosis. (**a**)The shaded area under the ROC curve (AUC) is 0.795, with a cut-off value of 0.653 (0.750, 0.745).(**b**) The validation group consisted of patients who had grade 1 ascites excluded, The shaded area under the ROC curve (AUC) is 0.812, with a cut-off value of 0.647 (0.756, 0.807). Abbreviation: Alb, albumin; SCr, Serum creatinine;Na, Serum sodium

a linear association between hepatic encephalopathy risk and serum sodium (109–168 mmol/L) [31], indicating its link to HE. We included Na + as an independent risk factor (OR = 0.84, $P = 0.007$), with higher levels associated with 0.88 times lower ascites risk. Hypervolemic hyponatremia, mainly caused by increased AVP, is common in cirrhosis. Meta-studies showed maintaining Na + with tolvaptan improves cirrhosis, ascites, and survival [32]. Including Na + in the nomogram allows better predictive score delineation.

In cirrhosis, reduced Alb synthesis decreases plasma colloid osmotic pressure, causing fluid leakage into the

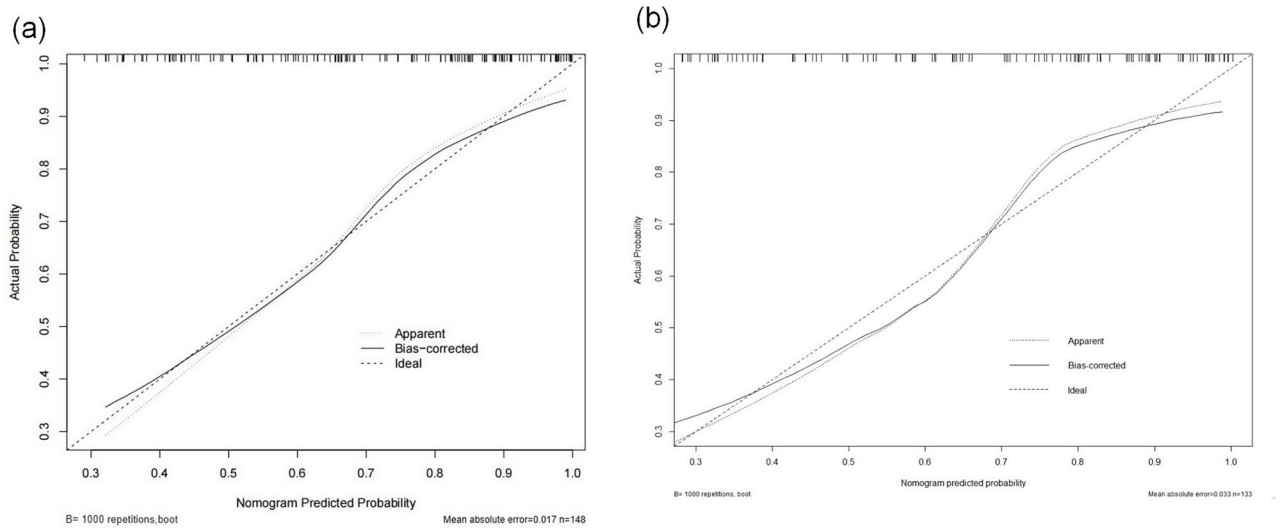

Fig. 4 A nomogram calibration curve is used to predict the probability of ascites. The ideal line, represented by a dashed diagonal line, shows perfect prediction. The solid line represents the actual predictive power of the nomogram. The closer the solid line is to the ideal line, the higher the predictive accuracy of the nomogram.The x-axis is the predicted event rate for the patients; the y-axis is the actual event rate for the patients actually observed.(**a**) All patients (**b**) Patients with grade 1 ascites excluded

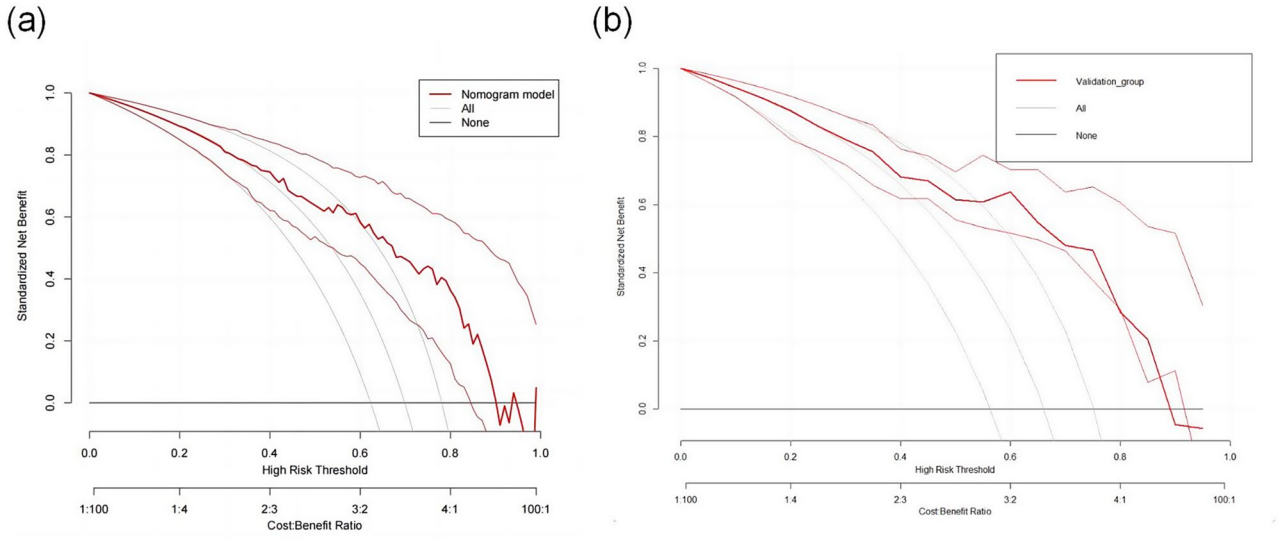

Fig. 5 Clinical decision curve analysis (DCA) for evaluating ascites prediction nomograms.(**a**) All patients (**b**) Patients with grade 1 ascites excluded

abdominal cavity and ascites. Long-term Alb treatment, though costly, reduces refractory ascites by 50% and improves 18-month survival [33]. We highlight Alb as a significant protective factor against cirrhotic ascites. The nomogram indicates a 7.5-point weight increase for every 5-unit Alb decrease. High Alb concentrations increase plasma osmotic pressure, causing volume expansion, inhibiting negative inotropic effects, and enhancing cardiac work [34]. Alb also alleviates immunosuppression and reduces cirrhosis decompensation risk by lowering prostaglandin E2 levels [35].

The Child-Pugh classification assesses liver function reserve in cirrhosis. We found Child-Pugh B and C patients more prone to ascites. This is due to the patient's poor liver function reserve and limited compensatory capacity for decompensation events [36]. Additionally, patients with new ascites frequently experience acute decompensation events, such as gastrointestinal bleeding and hepatorenal syndrome (HRS). Gastrointestinal bleeding can result in decreased blood volume and deteriorating renal function, which further exacerbates portal hypertension and ascites formation [37]. Furthermore, hepatorenal syndrome can intensify fluid retention and contribute to the recurrence of ascites [38].However, the MELD score (creatinine, INR, bilirubin) has broader predictive accuracy for cirrhotic ascites. Kartoun

et al. developed MELD-Plus, including serum albumin, improving cirrhosis score prediction by 16.9% [39]. Combining MELD-Plus and the nomogram is crucial for guiding cirrhosis and ascites treatment decisions.

We developed a prediction model using objective laboratory and endoscopic data, eliminating subjective bias and resulting in a more comprehensive and accurate model. Visual line graphs make predictions easier to comprehend. Blood biochemistry provides organ function insights, while electrolytes indicate acid-base balance. Variceal veins and bleeding are common causes of emergency admission in decompensated cirrhosis, highlighting their significance. Alb is widely accepted as an index for liver function and nutritional status.

This study has limitations. The small sample size warrants larger, multi-center, prospective studies. Alcoholic and hepatitis B cirrhosis account for a significant proportion, but some patients have cryptogenic cirrhosis with unclear causes. Including different cirrhosis etiologies may introduce bias. Patients were not continuously followed up, and further research is needed to explore time lapse impact on cirrhotic ascites probability prediction.

In 148 decompensated cirrhotic patients, we found higher ascites risk associated with variceal veins, bleeding, albumin, creatinine, and serum sodium. The nomogram based on these factors allows clinicians to identify high-risk patients and initiate timely interventions to reduce cirrhotic ascites risk.

Abbreviations

AG	Ascites group
NAG	Non-ascites group
DCA	Decision Curve Analysis
ROC	Receiver operating characteristic curve
CC	Calibration curve
HE	Hepatic encephalopathy
BI	Bacterial infections
HRS	Hepatorenal syndrome
Alb	Albumin
ALT	Alanine aminotransferase
AST	Aspartate aminotransferase
ALP	Alkaline phosphatase
TBil	Total bilirubin
TC	Total cholesterol
PT	Prothrombin time
INR	International normalized ratio
WBC	White blood cell count
Hb	Hemoglobin
NEUT	Absolute neutrophil count
SCr	Serum creatinine
Na	Serum sodium
HVPG	Hepatic venous pressure gradient
MAIT	Mucosal Associated Invariant T

Acknowledgements
Fengyi Xiong, Haoyu Tang, Yihao Lai conducted the data collection.

Author contributions
WW provided research ideas and manuscript revision. XLZ analyzed the data and was the main contributor in writing the manuscript. All authors read and approved the final manuscript.

Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The Ethics Committee of the Second Affiliated Hospital of Zhejiang University School of Medicine approved this study (I2024213), and informed consent was obtained from each patient.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 28 May 2024 / Accepted: 16 May 2025
Published online: 22 May 2025

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