Microbes and Infectious Diseases 2025; 6(4): 6432-6444

Microbes and Infectious Diseases

Journal homepage: https://mid.journals.ekb.eg/

Original article

Diagnostic performance of different scores for predicting spontaneous bacterial peritonitis in cirrhotic patients

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ARTICLE INFO

Article history:
Received 27 November 2024
Received in revised form 21 December 2024
Accepted 24 December 2024

Keywords:
Liver cirrhosis
Spontaneous bacterial peritonitis
Mansoura score
PEC index.

ABSTRACT

Background: Spontaneous bacterial peritonitis (SBP) is a severe complication in cirrhotic patients with ascites. Numerous scores were proposed for SBP diagnosis with variable accuracies. **Aim:** To evaluate the diagnostic accuracy of procalcitonin (PCT), neutrophil/lymphocyte ratio (NLR), PCT, erythrocyte sedimentation rate, and C-reactive protein index (PEC index), and modified Wehmeyer and Mansoura scoring systems for SBP in cirrhotic patients with ascites. **Methods**: This cross-sectional hospital-based study included 81 adult cirrhotic patients with ascites admitted to the Tropical Medicine and Gastroenterology Department, Sohag University Hospital. Ten ml of fresh venous blood was obtained to assess serum PCT, complete blood count (CBC), transaminases, and prothrombin time (PT). NLR, PEC index, modified Wehmeyer, and Mansoura scoring systems were calculated and the Receiver Operator Characteristic (ROC) curve was used to evaluate their diagnostic accuracy for SBP. **Results:** SBP was diagnosed in 25 patients (30.68%). Fever, diarrhea, abdominal pain, and jaundice were significantly higher in SBP (p < 0.001, <0.001, 0.046, 0.018). The area under the ROC curve (AUC) of neutrophil/lymphocyte ratio (NLR), PEC index, Mansoura score, and Model of End Stage Liver Disease (MELD) score for SBP diagnosis was 0.7 at cutoff values of 3.6, 19.3, 3, and 17, respectively (p< 0.05). **Conclusions:** Regarding the scores that were compared, the NLR proved to have the highest sensitivity in identifying SBP, while the Mansoura score was the most specific. Risk factors like fever, diarrhea, abdominal pain, and high serum bilirubin were positively related to SBP.

Introduction

Cirrhotic patients have an altered defense against bacteria associated with reduced bacterial clearance. This immune defect facilitates bacterial translocation induced by increased intestinal permeability and gut bacterial overgrowth. Therefore, bacterial infection is either present on admission or develops during hospitalization in about 30% of patients with cirrhosis, and the most common form of these infections is spontaneous bacterial peritonitis (SBP) [1-3].

SBP is a severe complication in cirrhotic patients with ascites. Cirrhotic ascites is transudative fluid with poor opsonic activity, which provides a favorable environment for growth of bacteria. The prevalence of SBP is 1.5–3.5% among outpatients and 10–30% among hospitalized patients. When first reported, in-hospital mortality

DOI: 10.21608/MID.2024.339642.2367
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from an episode of SBP exceeded 90%; however, this rate has been lowered to approximately 20% through early diagnosis and prompt antibiotic therapy [4-6].

The presence of infected ascitic fluid without known intra-abdominal cause is defined as SBP [7]. SBP is diagnosed upon positive ascitic bacteriological culture and/or absolute neutrophil count (polymorphonuclear cell (PMN)) within ascitic fluid of ≥250 cells/mm^3) [7].

Spontaneous bacterial peritonitis should be suspected in patients with cirrhosis who develop signs or symptoms such as fever, abdominal pain, altered mental status, abdominal tenderness, or hypotension [7-8].

Diagnostic paracentesis is not suitable to be performed in all cirrhotic patients as there are contraindications which include: absolute contraindications as disseminated intravascular coagulation and an acute abdomen requiring surgery, while the relative contraindications are pregnancy, organomegaly, ileus, intestinal obstruction, distended bladder as well as clotting derangements (i.e. severe thrombocytopenia where platelets are less than 20 × 10^3/μL and an international normalized ratio (INR) more than 2.0) [9].

As such contraindications and disadvantages, there is a real need to find a noninvasive prognostic scoring system to predict patients more liable to develop SBP, as prompt treatment could reduce the mortality rate. Multiple laboratory tests have been introduced as predictive for SBP, including C-reactive protein (CRP) level, platelets count, impaired prothrombin time (PT), serum creatinine level, bedside liver disease scoring systems like Child-Pugh and the Model of End-stage Liver Disease (MELD) scores [10-13]. Moreover, numerous scores were proposed for SBP diagnosis with variable accuracies, such as procalcitonin (PCT), erythrocyte sedimentation rate (ESR) and CRP (PEC) index [14], the modified Wehmeyer SBP scoring system [15], and the Mansoura scoring system [16]. Thus, the current study was conducted to evaluate the diagnostic accuracy of serum procalcitonin (PCT), neutrophil/lymphocyte ratio (NLR) PEC index, and modified Wehmeyer, and Mansoura scoring systems for SBP in cirrhotic patients with ascites.

Patients and methods

Study design, population, and settings

The current study is a cross-sectional hospital-based diagnostic accuracy study that included 81 adult patients with liver cirrhosis and ascites admitted to the Department of Tropical Medicine and Gastroenterology, Sohag University Hospital from March 2023 to September 2023 for different indications. We included all patients who were admitted during this period and fulfilled the predetermined inclusion and exclusion criteria.

Inclusion criteria

Adult patients (≥18 years old) with liver cirrhosis and ascites who accepted to participate in the study. The diagnosis of liver cirrhosis was based on abdominal ultrasound [17]. Ascites was detected either clinically or by ultrasound.

Exclusion criteria

Patients with infections other than SBP, those with Hepatocellular carcinoma (HCC) or other malignancies, those who were receiving antibiotics prior to hospital admission, those who received chemotherapy or radiotherapy within 1 month before admission, those with pancreatic diseases, those with renal affection, and those with any contraindication to paracentesis, e.g., disseminated intravascular coagulopathy were excluded.

The severity of liver disease was evaluated with Modified Child-Pugh [18], MELD [19], and MELD sodium (MELD-Na) [20] scores.

Procedure

All participants were subjected to clinical evaluation with emphasis on manifestations suggesting SBP (fever, abdominal pain, vomiting, diarrhea, hepatic encephalopathy, and jaundice) [21]. Under complete aseptic conditions, 10 ml of fresh venous blood was obtained from all patients :3 ml of blood in EDTA tube for complete blood count (CBC) by Sysmex (XN-1000) automated hematology analyzer, 2 ml blood in sodium citrate tube and 5 ml in plane tube for serum samples, and the following tests were done: CBC with calculation NLR, PT, prothrombin concentration (PC), INR were done from citrated plasma by Sysmex (CS-1600) coagulation analyzer. Serum albumin, serum bilirubin, alanine transaminase (ALT), aspartate transaminase (AST), and serum creatinine were done by AU 480 auto analyzer (Bechman Coulter). ESR was estimated using the Westergren method [22]. CRP was done by Atlas Medical kit which is a CRP latex reagent kit based on the principle of latex

agglutination assay. Serum PCT was done by automated ECL immunoassay analyzer eCL8000.

On the first day of admission and before receiving any antibiotic therapy, ascitic fluid samples were aspirated under complete aseptic conditions. The samples were examined physically for turbidity and were analyzed for ascitic protein, total and differential white blood cells, neutrophils, and lymphocytes. The samples were sent immediately to the clinical and chemical pathology laboratory to be processed.

First the ascitic fluid samples were cultured on blood agar (Himedia, India), and cultured on differential MacConkey medium (Himedia, India), and incubated at 37 c^o for 24-48 hours. On colony growth, subculture was done on EMB medium. From the same sample, at the same time, was cultured anaerobically on MacConkey medium in the anaerobic Gas pack system (BD Gas Pak™ Anaerobic System, Complete anaerobic conditions, using sachets from (BBL Gas Pak™ EZ Anaerobic Indicator Sachets, Ref 260001) and was incubated for 48 hours. SBP was diagnosed by the presence of PMN cell count in the ascitic fluid of at least 250 cells/ml^3, irrespective of the positivity ascitic fluid culture [21]. Based on ascitic fluid study, patients were categorized into two groups: patients with SBP (SBP group), and patients without SBP (non-SBP group).

- **Assessment of Serum Procalcitonin:**

According to the protocol manufacture in the processing of samples by using sample serum; PCT was estimated by an electrochemluminescence with its reference interval is <0.052 ng /ml, the result can be used to aid in the early detection of clinically relevant bacterial infections with PCT value < 0.5 ng /ml represents a low risk of sepsis and PCT > 2.0 ng /ml represents a high risk of severe sepsis.

The following scores were calculated for all patients:

- CRP/albumin ratio (CRA)
- The PEC index was calculated using the formula; PEC index = PCT × (ESR + CRP) [14].
- Modified Wehmeyer score was calculated as weighted sum of three categories (age, platelet count, and CRP). We gave one point for age >60 years, one point for platelet count <100,000/mm^3, one point for CRP levels between 30 and 60 mg/L, and two points for CRP levels above 60 mg/L. The score ranges from 0-4 points [15].
- Mansoura score was calculated as a weighted sum of four categories (age, mean platelet volume (MPV), NLR, and CRP) we gave one point for age ≥55 years, one point for MPV ≥8.5 fL, one point for NLR≥2.5, and two points for CRP≥40 mg/L. The score ranges from 0–5 points [16].

Ethical considerations

This work was carried out in accordance with the Declaration of Helsinki and a written informed consent was obtained from all participants. Confidentiality of data was assured, and data collection forms were anonymous. The study protocol was approved by the Scientific Research Ethical Committee of Faculty of Medicine, Sohag University under IRB Registration number Soh-Med-22-12-25. The protocol was registered on Clinical trials under registration number NCT05696054.

Statistical Analysis

Data were analyzed using IBM Statistical Package for Social Science (SPSS) Statistics for Windows version 20.0 and MedCalc software version 15.8.0. Quantitative data were expressed as median and interquartile range (IQR). Qualitative data were expressed as numbers and percentages. Data were tested for normality using the *Shapiro-Wilk* test. Independent samples *t-test* was applied for normally distributed data. The nonparametric Mann–Whitney test was used for data not normally distributed. The *Chi-square ($\chi 2$)* test and *Fisher's Exact* Test were used for the comparison of qualitative variables as appropriate.

The receiver operating characteristic (ROC) curve was constructed for optimum cut-off points of the studied measures in predicting spontaneous bacterial peritonitis and the area under the ROC curve (AUC) value with a 95% confidence interval (CI) was calculated. Optimal cut-off values were determined; sensitivity, specificity, positive predictive value, negative predictive value, and Youden index were calculated. A 5% level was chosen as a level of significance in all statistical tests used in the study.

Results

The current study included 81 cirrhotic patients with ascites, their ages ranged from 17 to 81 years old, and 47 (58%) of them were males. Based

on ascitic fluid neutrophilia, 25 patients (30.68%) were diagnosed as SBP patients **(Figure 1)**.

Clinical and demographic data:

Concerning the comparison between the two study groups regarding age, gender, and clinical features, **Table 1** shows that there was a highly statistically significant difference between SBP and non-SBP groups regarding fever and diarrhea ($p < 0.001$). Also, abdominal pain and jaundice had statistically significant differences between both groups ($p = 0.046$ and 0.018, respectively).

Laboratory investigations:

Concerning the comparison between the two study groups regarding laboratory investigations results, **Table 2** mentions that neutrophilic counts and NLR were significantly higher in SBP group ($p = 0.013$). Serum bilirubin had a highly statistically significant higher value in SBP group compared to non-SBP group ($p < 0.001$).

Ascitic fluid study:

Regarding the comparison between the two study groups regarding criteria of ascitic fluid aspirate, **Table 3** shows that ascitic fluid turbidity was seen in 84% of the SBP group compared to 53.57% in non SBP group ($p = 0.009$). Ascitic fluid bacteriological cultures were negative in all patients of both groups.

The studied scores for SBP diagnosis:

About the comparison between the two study groups regarding the studied scores, **Table 4** shows that the all studied scores, namely; Modified Child-Pugh, MELD, MELD-Na, Mansoura, and Modified Wehmeyer scores, CRA ratio, NLR, and PEC index had statistically significant higher values in the SBP group compared to the non-SBP group ($p = 0.035$, 0.007, 0.035, 0.02, 0.029, 0.043, 0.015 and 0.014, respectively)

The diagnostic performances of PCT and the studied scores for SBP were evaluated using ROC curve statistics **(Table 5, Figure 2)** and most of them showed a significant diagnostic role where the sensitivity and specificity of NLR, at a cutoff value of 3.6, were 92% and 48.2% (AUC = 0.7; 95% CI 0.6–0.8), the sensitivity and specificity of the PEC index, at a cutoff value of 19.3, were 48% and 83.9% (AUC = 0.7; 95% CI 0.6–0.8), and the sensitivity and specificity of Mansoura score, at a cutoff value of 3, were 32% and 92.9% (AUC = 0.7; 95% CI 0.5–0.8). Moreover, the sensitivity and specificity of CRA, at a cutoff value of 5.2, were 72% and 58.9% (AUC = 0.6; 95% CI 0.5–0.7). The sensitivity and specificity of the Modified Wehmeyer score, at a cutoff value of 1, were 64% and 58.9% (AUC = 0.6; 95% CI 0.5–0.7). The sensitivity and specificity of the MELD-Na score, at a cutoff value of 21, were 72% and 57.1% (AUC = 0.6; 95% CI 0.5–0.8).

Table 1. Comparison between the two study groups regarding age, gender, and clinical features.

Characteristics	Non-SBP group (N= 56)	SBP group (N= 25)	P-value
Age			
Median (IQ range)	**62 (55.5 – 70)**	**60 (53.5 – 65)**	0.111
Sex			
Male	**30 (53.57%)**	**17 (68%)**	0 .224
Female	**26 (46.43%)**	**8 (32%)**	
Fever	**4 (7.14%)**	**11 (44%)**	**<0 .001**
Abdominal pain	**9 (16.07%)**	**9 (36%)**	**0 .046**
Vomiting	**3 (5.36 %)**	**1 (4%)**	1
Diarrhea	**3 (5.36 %)**	**10 (40%)**	**<0 .001**
Jaundice	**16 (28.57%)**	**14 (56%)**	**0 .018**
Hepatic encephalopathy			
No	**19 (33.93%)**	**6 (24%)**	0 .840
Grade I	**30 (53.57%)**	**14 (56%)**	
Grade II	**5 (8.93 %)**	**3 (12%)**	
Grade III	**1 (1.79 %)**	**1 (4%)**	
Grade IV	**1 (1.79 %)**	**1 (4%)**	

IQ: interquartile, SBP: spontaneous bacterial peritonitis

Table 2. Comparison between the two study groups regarding laboratory investigations results.

Characteristics	Non-SBP group (N= 56)	SBP group (N= 25)	P-value
WBCs ($\times 10^3$ /mm^3) Median (IQ range)	6.45 (3.71 – 9.3)	9.1 (4.55 – 14.1)	0.079
Neutrophils ($\times 10^3$ /mm^3) Median (IQ range)	3.88 (2.39 – 6.4)	7.2 (3.15 – 11.3)	0.013
Lymphocytes ($\times 10^3$ /mm^3) Median (IQ range)	1.04 (0.6 – 1.4)	1.07 (0.55 – 1.35)	0.898
Hemoglobin (g/dL) Median (IQ range)	9.9 (8.93 – 11.23)	10.9 (9.15 – 12)	0.238
Platelets ($\times 10^3$ /mm^3) Median (IQ range)	115 (72.25 – 187.75)	99 (43.3 – 176.5)	0.274
MPV (fL) Median (IQ range)	9.6 (7.83 – 10.7)	10 (8.17 – 11.1)	0.489
ESR (mm/hour) Median (IQ range)	30 (18.5 – 60)	50 (19 – 67.5)	0.407
CRP (mg/L) Median (IQ range)	9 (0 – 24)	24 (3 – 48)	0 .063
PT (seconds) Median (IQ range)	15.7 (14.05 – 17.65)	16.4 (15.2 – 19.8)	0 .061
PC (%) Median (IQ range)	60.45 (47.68 – 68.28)	50.8 (44.3 – 61.85)	0.069
INR Median (IQ range)	1.3 (1.2 – 1.6)	1.4 (1.3 – 1.75)	0.124
Na (mm/L) Median (IQ range)	130 (124.15 – 134)	129.5 (124 – 131)	0.346
Serum creatinine (mg/dL) Median (IQ range)	1 (0.7 – 1.5)	1 (0.75 – 1.7)	0 .340
Bilirubin (mg/dL) Median (IQ range)	1.6 (0.8– 2.48)	4.3 (1.8 – 7)	<0.001
Albumin (g/dL) Median (IQ range)	2.4 (2.13 – 2.88)	2.2 (1.8 – 2.85)	0.081
ALT (IU/L) Median (IQ range)	19 (12 – 30)	26 (12 – 45.5)	0.223
AST (IU/L) Median (IQ range)	37 (26.25 – 59.75)	50 (30 – 122.5)	0.05
PCT (ng/mL) Median (IQ range)	0.09 (0.07 – 0.2)	0.26 (0.08 – 0.4)	0.051

ALT: alanine transaminase, AST: aspartate transaminase, CRP: C-reactive protein, ESR: erythrocyte sedimentation rate, IQ: interquartile, INR: international randomized ratio, MPV: mean platelet volume, Na: sodium, NLR: neutrophil/lymphocyte ratio, PC: prothrombin concentration, PCT: procalcitonin, PT: prothrombin time, SBP: spontaneous bacterial peritonitis, WBCs: white blood cells.

Table 3. Comparison between the two study groups regarding criteria of ascitic fluid aspirate.

Characteristics	**Non-SBP group (N= 56)**	**SBP group (N= 25)**	**P-value**
Ascitic fluid aspect Clear Turbid	 26 (46.43%) 30 (53.57%)	 4 (16%) 21 (84%)	**0.009**
Protein Median (IQ range)	 1.25 (0.9– 2.1)	 1.1 (0.85 – 1.7)	0.258
WBCs Median (IQ range)	 117.5 (43.75 – 270)	 600 (382.5 – 1637.5)	**<0.001**
Neutrophil Median (IQ range)	 13.5 (4 – 41.75)	 452 (302 – 1305)	**<0.001**
Bacteriological culture Negative Positive	 56 (100%) 0	 25 (100%) 0	NAIQ

IQ: interquartile, NA: not applicable, SBP: spontaneous bacterial peritonitis.

Table 4. Comparison between the two study groups regarding the studied scores.

Characteristics	No-SBP group (N= 56)	SBP group (N= 25)	P-value
Modified Child Pugh score Median (IQ range)	**10 (9 – 11)**	**11 (9 – 12)**	**0.035**
Child class A B C	 **1 (1.79 %)** **22 (39.29%)** **33 (58.92%)**	 **0 (0.0%)** **9 (36%)** **16 (64%)**	 0 .735
MELD Median (IQ range)	 **13.5 (9.25 – 18)**	 **19 (14 – 21.5)**	**0.007**
MELD- Na Median (IQ range)	 **20 (16 – 26)**	 **26 (20 – 28)**	**0.035**
CRA Median (IQ range)	 **3.35 (0 – 9.73**	 **8.6 (1.1 – 17.6)**	**0.043**
NLR Median (IQ range)	 **3.75 (2.53 – 7.5)**	 **5.7 (4.5 – 8.25)**	**0.015**
PEC index Median (IQ range)	 **4.9 (2.7– 14.91)**	 **17.09 (4.75 – 40.14)**	**0.014**
Mansoura scoring system. Median (IQ range)	 **2 (2 – 3)**	 **3 (2 – 4)**	**0.02**
Modified Wehmeyer score Median (IQ range)	 **1 (1 – 2)**	 **2 (1 – 3)**	**0 .029**

CRA: C-reactive protein/albumin ratio, IQ: interquartile, MELD: Model of End Stage Liver Disease, MELD-Na: Model of End Stage Liver Disease sodium, PEC: procalcitonin, erythrocyte sedimentation rate, and C-reactive protein index, SBP: spontaneous bacterial peritonitis.

Table 5. Receiver operating characteristic (ROC) curve of the studied measures for optimum cut off points in predicting spontaneous bacterial peritonitis.

Marker	Cutoff	AUC	CI	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Youden index (%)	P-value
NLR	**>3.6**	**0.7**	**0.6 to 0.8**	**92**	**48.2**	**44.2**	**93.1**	**40.2**	**0.006***
CRA	**>5.2**	**0.6**	**0.5 to 0.7**	**72**	**58.9**	**43.9**	**82.5**	**30.9**	**0.048***
PCT	**>0.199**	**0.6**	**0.5 to 0.7**	**56**	**78.6**	**53.8**	**80**	**34.6**	0.052
PEC index	**>19.3**	**0.7**	**0.6 to 0.8**	**48**	**83.9**	**57.1**	**78.3**	**31.9**	**0.009***
Mansoura scoring system	**>3**	**0.7**	**0.5 to 0.8**	**32**	**92.9**	**66.7**	**75.4**	**24.9**	**0.025***
Modified Wehmeyer score	**>1**	**0.6**	**0.5 to 0.7**	**64**	**58.9**	**41**	**78.6**	**22.9**	**0.017***
MELD	**>17**	**0.7**	**0.6 to 0.8**	**64**	**73.2**	**51.6**	**82**	**37.2**	**0.002***
MELD-NA	**>21**	**0.6**	**0.5 to 0.8**	**72**	**57.1**	**42.9**	**82.1**	**29.1**	**0.024***

* Statistically significant

AUC: area under the curve, CI: confidence interval, CRA: C-reactive protein/albumin ratio, CRP: C-reactive protein, MELD: Model of End Stage Liver Disease, MELD-Na: Model of End Stage Liver Disease sodium, NLR: neutrophil/lymphocyte ratio, NPV: negative predictive value, PEC: procalcitonin, erythrocyte sedimentation rate, and C-reactive protein index, PCT: procalcitonin, PPV: positive predictive value.

Figure 1. Distribution of the studied patients according to spontaneous bacterial peritonitis (SBP). **`.**

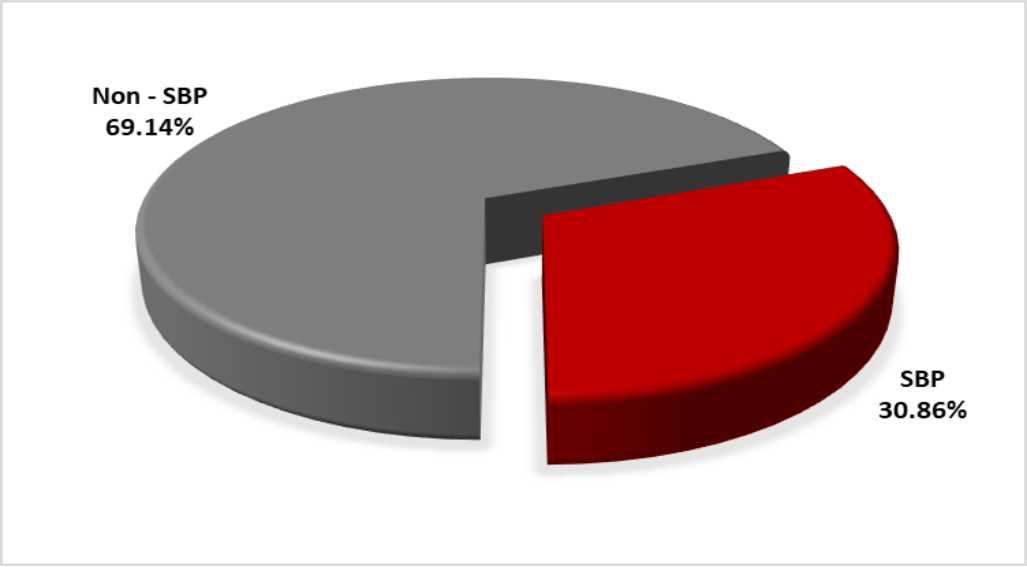
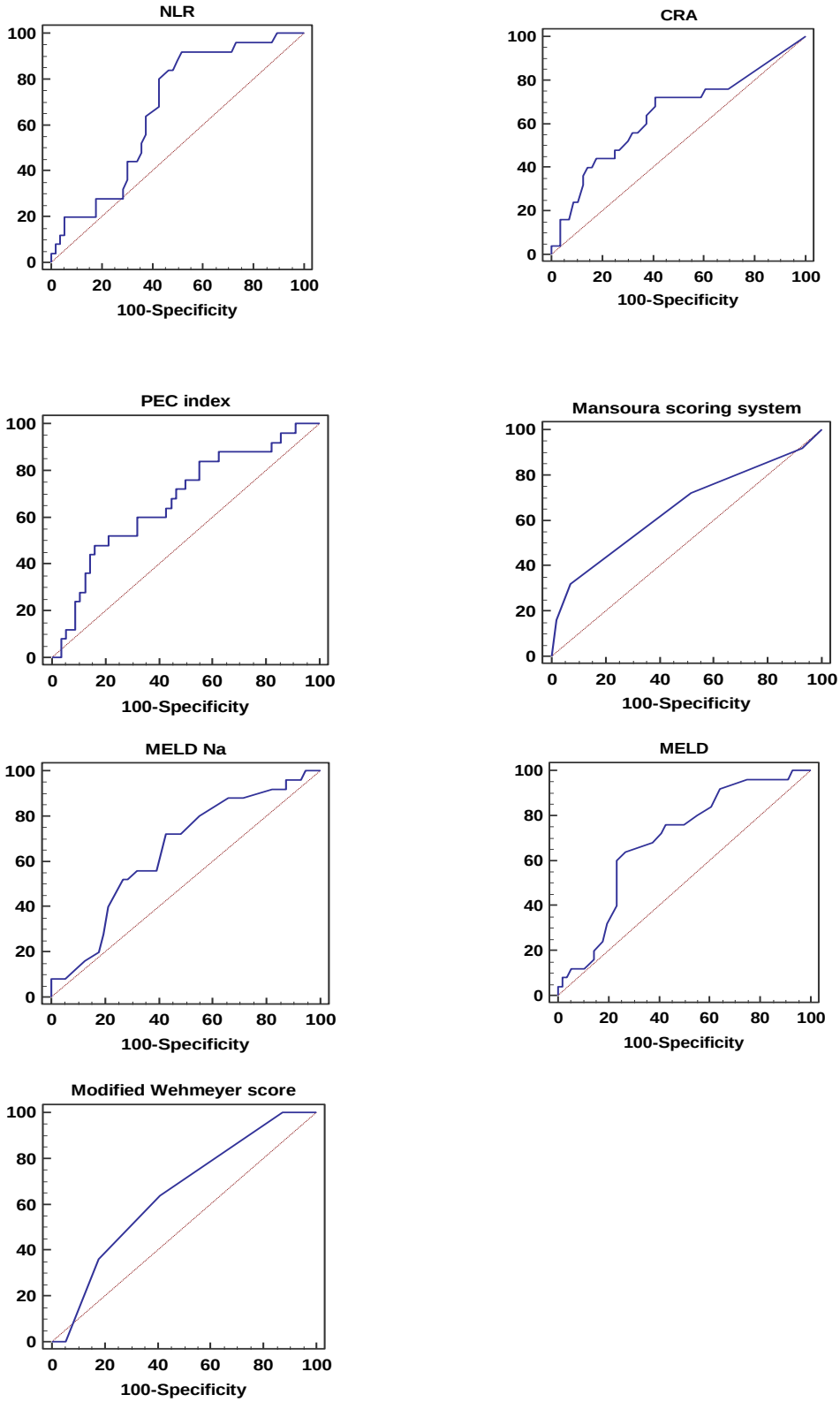


Figure 2. Receiver operating characteristic (ROC) curve of the studied measures for optimum cut off points in predicting spontaneous bacterial peritonitis.



CRA: C-reactive protein/albumin ratio, MELD: Model of End Stage Liver Disease, MELD-Na: Model of End Stage Liver Disease sodium, NLR: neutrophil/lymphocyte ratio, PEC: procalcitonin, erythrocyte sedimentation rate, and C-reactive protein index.

Discussion

SBP is a potentially life-threatening condition that complicates the natural history of cirrhosis and early identification, and treatment has been shown to both affect and modulate survival in these individuals [17].

In this study, there were significant differences in symptoms including fever, diarrhea, abdominal pain, and jaundice in the group of patients developing SBP. Other previous studies have consistently concluded that these factors are valid predictors of SBP. For example, according to Runyon et al [7] and Sola et al [23], fever and abdominal pain appeared as key presenting symptoms, which is consistent with our results. However, fewer studies have pointed out that diarrhea is one of the easily diagnosed signs of SBP. Hamrefors et al [24] sought to understand gastrointestinal symptoms which occurred in SBP, but diarrhea was less indicated. This may be due to differences in patient enrollment or because SBP manifests differently in the various regions.

The laboratory markers, including high neutrophil counts and raised NLR in the SBP group of this study, concord with previous research evidence. High neutrophil count in ascitic fluid is well incorporated into existing clinical diagnostic criteria for SBP in various clinical practice guidelines, including the American Association for the Study of Liver guidelines [25]. Spontaneous bacterial peritonitis is a severe complication in cirrhosis patients and timely diagnosis is crucial to manage and reduce mortality in these patients.

Another reason for selecting the NLR as a marker of inflammation is that it has also emerged as an effective tool in identifying SBP. Seyedi et al. [26] revealed a significant relationship between NLR and SBP because NLR denotes inflammation anywhere in the body, which is typical in infection-induced liver impairment. However, concerning the levels of NLR as described in our study and that of Seyedi et al, there are slight disparities in the sensitivity and specificity because of dissimilar thresholds and patients' population characteristics.

For the NLR at threshold of 3.6 our study yielded high sensitivity of 92% but less specificity of 48.2% for suspected SBP. This is similar to findings revealed by Shi et al [27] and Mustika & Waafi [28] describing NLR as an optimal biomarker for cirrhosis-related infections, though with other cutoffs. Shi et al. found similar sensitivity at different cut-off levels while presenting a higher specificity when NLR was accumulated with the other biomarkers. The variability in our study might be due to employing a single marker that integrated into clinical signs to improve NLR's discrimination could improve its diagnostic.

Regarding the prediction of SBP, the applicability of Modified Child-Pugh score has been reported to be inconsistent and variable. Based on the study, Child-Pugh scores were statistically higher in the SBP study patients, similar to the study conducted by Ponziani et al [29] who noted that patients with higher Child-Pugh scores were more vulnerable to SBP because of a compromised immune system. Nevertheless, the value of this score in estimating SBP is not highly accurate as it was developed to predict mortality, not infection.

The MELD and MELD-Na scores for predicting the mortality in cirrhotic patients were also higher in SBP patients in the current study. In a similar fashion, both Hong et al [30] and Godfrey et al [31] specified that the infection risks are higher with worse liver function because of higher MELD scores. In particular, MELD-Na has been described in the cited literature, including Biggins et al [25], as a more accurate predictor in case of hyponatremia. The sensitivity and specificity of 0.70 and 0.68 we obtained in our study are consistent with these results, which reinforce the value of MELD-Na in selecting patients at risk for SBP. However, our study showed that MELD-Na had a modest AUC of 0.6, which means that when used solo, it can barely predict SBP with great certainty. This concords with Coxeter-Smith et al [32] who posited that using other inflammatory indices in combination with MELD may increase the predictive capability of infections such as SBP.

Mansoura and Modified Wehmeyer tests were equally useful in the differentiation of SBP cases from non–SBP in the current study but with high specificity albeit moderate sensitivity. Abdel-Razik et al [33] generated the Mansoura score specific to SBP prediction in Egyptian populations, which demonstrated similar specificity results to the current study but slightly different sensitivity outcomes. These differences could be as a result of ethnic and geographical differences in the progression of liver disease and infection rates. Metwally et al [15] also showed that the specificity of the Modified Wehmeyer score's ability to identify cases of SBP was about 59%, similar to our study. These results are consistent with the study's

original findings; nonetheless, the sensitivity in Wehmeyer's research was marginally higher, which may be attributed to differences in the SBP criteria or clinicians' interpretations of scores.

The ROC analysis in our study involved all the scores and moderate AUC values were obtained highlighting the fact that none of the scores could become diagnostic for SBP. ROC values are also in tune with this trend in prior research, where multiple values offer diagnostic information, yet none equals one. For instance, a study by Kim et al [34] highlighted MELD score and its discriminating potential yielding similar AUC values as drawn in our moment confirming that MELD without the help of other factors can't independently categorize SBP cases. Likewise, in their work, Mouchli et al [35] showed that integrating scores (MELD with CRP or NLR) enhanced diagnostic accuracy, opening the possibility of assessing compound scores.

Novel diagnostic paradigms suggest supplementing molecular biomarkers with clinical ratings to enhance the prognostication of SBP. Serological markers such as PCT and CRP have become popular in diagnosis of SBP and appear to be effective in identification of infection. Chirapongsathorn et al [36] and Godfrey et al [31] provide a suggestion that CRP, together with scores such as MELD, can increase diagnostic precision.

Conclusions

Overall, this research aimed to assess the diagnostic accuracy of different scores in estimating the development of SBP in cirrhotic patients with ascites. Regarding the scores that were compared, the NLR proved to have the highest sensitivity in identifying SBP, while the Mansoura score was the most specific. Risk factors like fever, diarrhea, abdominal pain, and high serum bilirubin were positively related to SBP, which necessitates thorough clinical and laboratory investigations in a high-risk population.

Limitations and Future Directions

This paper focuses on the ability and deficiencies of different scoring systems used in identifying SBP in patients with cirrhosis. Given the limited sample size, it can only recommend moderate diagnostic accuracy, which means that there could still be certain cases of SBP being overlooked or diagnosed unnecessarily. All cultures were negative, which may raise concerns about culture sensitivity or differences in microbial flora in different regions. The use of conventional culture methods without blood culture bottles, which were unavailable, may have contributed to the negativity of our cultured samples. However, previous literature reported a non-significant difference between ascitic fluid samples directly inoculated on conventional plates and those preceded by inoculation into blood culture bottles [37].

Further studies should be aimed at the validation of these scores with a bigger group of patients from different centers. Machine learning approaches may also help enhance diagnostic accuracy by dealing with these types of data and lead to composite scores that consider unique clinical characteristics. These developments are to help in identifying the patients at risk of SBP earlier and ensure the improvement of their prognosis.

Declarations

- **Ethics approval and consent to participat**e: This work was carried out following the Declaration of Helsinki and written informed consent was obtained from all participants. Ethical approval was obtained from the Scientific Research Ethical Committee, Faculty of Medicine, Sohag University (IRB: S Soh-Med-22-12-25). ClinicalTrials.gov Identifier: NCT05696054.
- **Consent for publication:** Not applicable.
- **Availability of data and material:** The required data and materials are all available.
- **Competing interests:** The authors declare that they have no competing interests.
- **Funding:** This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
- **Authors' contributions:** RMM collected participant's data. NMA analyzed and interpreted the patient data. SRA and NSS performed the laboratory work up. HSM and AM were major contributors in writing the manuscript. All authors read and approved the final manuscript.
- **Acknowledgements:** Not applicable.

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