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A novel serum index for accurate diagnosis of spontaneous bacterial peritonitis in cirrhotic patients without other infections

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Abstract

Background: The accurate non-invasive diagnosis of spontaneous bacterial peritonitis (SBP) in patients with decompensated liver cirrhosis has not been achieved yet. The aim of the study was to obtain an unmistakable diagnosis of SBP using a new simple serum bioscore, made by combined measurement of procalcitonin (PCT), erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP), which we called the PEC index. This cross-sectional analytic study comprised 178 cirrhotic patients with ascites (60 patients with SBP and 118 patients with sterile ascites), after excluding non-SBP infection, during the period from March 2019 until September 2019. In all participants, serum levels of PCT, ESR, and CRP were measured, and PEC index was calculated [PEC index = PCT × (ESR + CRP)].

Results: Patients with SBP (n = 60) had significantly higher serum PEC index than those with sterile ascites (n = 118) (41.0/31.2–93.0 vs. 9.9/5.9–15.0, P < 0.001). PEC index distinguished culture positive cases significantly (P < 0.001). Using receiver operating characteristic (ROC) statistics, the sensitivity and specificity of PCT, at a cutoff value of 0.590 ng/mL, for SBP diagnosis, were 81.67% and 93.33%, respectively (area under the curve [AUC] = 0.879; 95% confidence interval [CI] 0.809–0.948). The sensitivity and specificity of ESR, at a cutoff value of 27.0 mm/hour, were 73.33% and 61.67%, respectively (AUC = 0.679; 95% CI 0.581–0.776). The sensitivity and specificity of CRP, at a cutoff value of 21.0 mg/L, were 93.33% and 51.67%, respectively (AUC = 0.736; 95% CI 0.639–0.833). While, the sensitivity and specificity of PEC index, at a cutoff value of 20, were highest (98.33% and 96.67%, respectively, AUC = 0.977; 95% CI 0.940–0.996).

Conclusion: Serum PEC index makes an accurate noninvasive diagnosis of SBP, after excluding other infections.

Keywords: Cirrhosis, Spontaneous bacterial peritonitis, Procalcitonin, PEC index

Background

Spontaneous bacterial peritonitis (SBP) is the commonest life-threatening infection encountered in cirrhotic patients with ascites. It accounts for more than half of all infections [1–3].The outpatient prevalence of SBP is 1.5–3.5% and exceeds 10% in hospitalized patients [4, 5].

The immune dysfunction in decompensated cirrhotic patients (DCPs) along with vulnerability of gut mucosa leading to translocation of bacteria and bacterial endotoxins from bowel lumen into ascitic fluid (AF), underlie the pathogenesis of SBP [1, 6–8].

SBP precipitates several other complications of cirrhosis, e.g., impairment of hepatic status, hepatic encephalopathy, worsening of coagulopathy, variceal bleeding, renal failure, and even death [9]. In former decades, SBP was associated with > 90% mortality that has been reduced nowadays to ~ 20% with the development of prompt diagnosis and appropriate therapy [9, 10].

Typically, SBP presents with abdominal pain and tenderness associated with fever. However, it may present with other local symptoms and signs of peritonitis as vomiting, and ileus; other manifestations of systemic inflammation as hypothermia, chills, tachycardia, tachypnea, and shock; worsening of liver or kidney functions; or hepatic encephalopathy [11]. SBP may also be asymptomatic in 10% of cases [4].

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Though, a positive AF culture for a pathogen is the gold standard for SBP diagnosis, about 60% of cases with clinical manifestations indicative of SBP and increased AF polymorphonuclear leukocytic (PMNL) count have negative cultures. Consequently, an AF PMNL count ≥ 250/μL is considered for SBP diagnosis, regardless of culture results [12–15]. In considerable number of cases, the absence of typical clinical characteristics of SBP makes its identification difficult [16].Therefore, an early non-invasive diagnosis of SBP in DCPs is sometimes recommended, especially in cases with irrelevant clinical manifestations, those newly admitted to hospital, or those with unexplained shock or deterioration of their liver functions [2, 3, 16].

Several non-invasive methods were tried in many studies for SBP diagnosis, as alternatives to diagnostic paracentesis, with variable accuracies, e.g., clinical scores [17], fecal calprotectin [18], and numerous serum inflammatory cytokines and chemokines such as monocyte chemotactic protein-1, interleukin-10 [19], human neutrophil peptide [20], platelet indices [21], macrophage inflammatory protein-1 beta [22], interferon-γ-induced protein-10, tumor necrosis factor-α, and interleukin-6 [23]. However, none of these methods was accurate enough to replace diagnostic paracentesis.

Procalcitonin (PCT) is a 116-amino acid polypeptide precursor of calcitonin with a molecular weight of 13 KDa produced by extra-thyroidal cells (e.g., monocytes) [24]. It has been proposed in highly cited studies as a potentially valuable serum biomarker to diagnose bacterial infections in general [24–26] and SBP in particular [27–30]. Normally, serum PCT level is undetectable (< 0.01 ng/mL), and it rapidly increases in case of infection [26].

Although the reported average estimate of sensitivity and specificity of serum PCT for SBP diagnosis in different clinical trials were relatively high (83% and 92%, respectively) [27], this performance was insufficient to make an acceptable accurate diagnosis. In order to achieve a more reliable diagnostic accuracy of PCT, we have tried a combined measurement of serum PCT with serum erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) to formulate a novel serum index for SBP diagnosis that we called, the PEC index.

Methods

Study design and sitting

This cross-sectional analytic study was carried out on 178 consecutive hospitalized cirrhotic patients with ascites admitted to internal medicine and tropical medicine departments, in collaboration with the Clinical Pathology Department, Faculty of Medicine, Zagazig University Hospital, Egypt, from March 2019 until September 2019.

Participants

Out of 257 consecutive hospital admissions of potentially eligible cirrhotic patients with ascites, 62 patients who had non-SBP infections were excluded and 7 patients died before the sampling procedures. Eligibility for the study was confirmed in 188 patients; of them, only 178 patients accepted to participate in the study.

Inclusion criteria

1. Adult patients ≥ 18 years
2. All consecutive hospitalized DCPs with moderate to severe ascites (that was detected clinically and confirmed with abdominal ultrasonography) who were admitted for different purposes like clinically suspected SBP, variceal bleeding, and hepatic encephalopathy. Participants were classified into an SBP group (either symptomatic or asymptomatic) (n = 60) and a sterile ascites group (n = 118).

The diagnosis of SBP was confirmed by an AFPMNL count ≥ 250/mm^3 with or without a positive ascitic fluid culture for pathogenic bacteria. Absence of both criteria meant the ascites was sterile [14, 15].

Exclusion criteria

1. Patients with a diagnosed infection other than AF infection, e.g., upper and lower respiratory tract infection, urinary tract infection, and otitis media
2. Patients with HCC or associated pancreatic disease, as these conditions could affect the components of PEC index.
3. Patients who received antibiotics 10 days prior to hospital admission.
4. Patients with AF culture positivity and AF PMNL count < 250/mm^3 (bacterascites)
5. Patients who refused to be enrolled in the study or refused to sign the consent.

Study tools

All included patients were subjected to thorough clinical assessment, abdominal ultrasound scanning, routine laboratory examination, e.g., complete blood picture, liver function and kidney function tests, coagulation profile and viral markers, and determination of serum levels of ESR (first hour), CRP (by Cobas 8000, Roch, Germany) and PCT, and peritoneal fluid examination.

Serum PCT measurement

This was done by the electrochemiluminescence immunoassay (ECLIA) on Cobas e 411 immunoassay analyzers, Roch, Germany, acting via the sandwich principle. The analyzer automatically calculates the analyte concentration

of each sample in ng/ml with a measuring range of 0.02 to 100 ng/ml and the coefficient of variability of 8% [31].

Peritoneal fluid examination technique

Sterile bedside diagnostic paracentesis was done using a 23-G needle attached to a 20 cc syringe after applying local anesthesia. Then, aspirated ascitic fluid was collected into two tubes and analyzed within 2 h of aspiration. The first tube for culture and sensitivity and second tube with ethylene diamine tetraacetic acid were to be analyzed for biochemistry and leukocyte counts.

PEC index

This is a new serum bioscore, innovated in this study, which was calculated by the formula; PEC index = PCT × (ESR + CRP). This formula was chosen on a statistical base, after repeated trials and errors while trying several different formulae.

Statistical analysis

Statistical analysis was performed with SPSS software, version 22.0 (SPSS Inc., Chicago, IL, USA). The continuous variables were expressed as means ± standard deviation (SD) and the categorical variables as count numbers and proportions. The suitable test was used, e.g., Student's *t* test, Mann–Whitney *U* test, Pearson's chi-squared test, Fisher's exact test, and Pearson's correlation test. The result was considered significant if $P \leq 0.05$. In order to test the diagnostic accuracy of various markers as well as the novel PEC index for diagnosis of SBP, we used receiver operating characteristic (ROC) statistics and determined sensitivity, specificity, and area under the curve (AUC) for each.

Results

Comparison between SBP group ($n = 60$) and sterile ascites group ($n = 118$) regarding demographic, clinical, and laboratory characteristics revealed significantly higher serum PCT, ESR, and CRP, as well as significantly higher AF LDH and PMNL count in SBP group ($P < 0.001$, for all parameters). Also, PEC index was significantly higher in SBP group than in sterile ascites group (41.0/31.2–93.0 vs. 9.9/5.9–15.0, $P < 0.001$) (Table 1).

AF bacterial culture positivity was found in 41.67% (25/60) of SBP group, but not in sterile ascites group at all (0/60) (Table 1). The commonest pathogens encountered were Escherichia coli in 68.0% (17/25) and Klebsiella in 16.0% (4/25) of culture positive cases. Positivity of AF culture among patients with SBP was significantly associated with higher levels of serum PCT, PEC index, AF LDH, and AF PMNL count and with lower AF glucose level ($P < 0.001$, for all) (Table 2).

ROC statistics were used to assess diagnostic accuracy of tested serum markers in SBP diagnosis (Figs. 1 and 2). The sensitivity and specificity of PCT, at a cutoff value of 0.590 ng/mL, were 81.67% and 93.33% (AUC = 0.879; 95% confidence interval [CI] 0.809–0.948). The sensitivity and specificity of ESR, at a cutoff value of 27.0 mm/h, were 73.33% and 61.67% (AUC = 0.679; 95% CI 0.581–0.776). The sensitivity and specificity of CRP, at a cutoff value of 21.0 mg/L, were 93.33% and 51.67% (AUC = 0.736; 95% CI 0.639–0.833) (Fig. 1 and Table 3). Serum PEC index, at a cutoff value of 20, had much higher sensitivity and specificity for SBP diagnosis (98.33% and 96.67%, respectively, AUC = 0.977; 95% CI 0.940–0.996), with an overall diagnostic accuracy of 97.50% (Fig. 2 and Table 3).

Figures 3 and 4 and Table 3 show the diagnostic performances of PEC index and its components in discrimination between cases with culture-negative SBP and those with sterile ascites. PCT, at a cutoff value of 0.305 ng/mL, was associated with a better diagnostic accuracy (AUC = 0.825; 95% CI 0.742–0.907) than that of ESR, at a cutoff value of 27 mm/h (AUC = 0.649; 95% CI 0.521–0.776) and that of CRP at a cutoff value of 23.5 mg/L (AUC = 0.704; 95% CI 0.613–0.794) (Fig. 3). PEC index, at a cutoff value of 20, was associated with the best diagnostic performance (AUC = 0.970; 95% CI 0.934–1.0) (Fig. 4).

Discussion

The search for a non-invasive and readily available biomarker for unmistakable diagnosis of SBP in cirrhotic patients with ascites, is still under clinical trials [22, 23, 29, 30, 32, 33]. The current work, to the best of our knowledge, is the first to characterize the use of indexed combined measurement of serum PCT, ESR, and CRP for this purpose, after exclusion of non-SBP bacterial infections.

In this study, all SBP patients ($n = 60$) had AF inflammatory response due to bacterial infection as was identified by AF PMNL count ≥ 250/HPF. Other biochemical findings in AF analysis confirmed the presence of infection like high LDH and low glucose. These findings were in accordance with that of Badawy et al. [34] and EL-Motasem et al. [35].

In addition, serum levels of acute phase reactants; ESR, CRP, and PCT in the SBP group of our patients (31/23–36 mm/h, 27/24–29 mg/L, and 0.691/0.604–1.690 ng/mL, respectively) were significantly higher than in sterile ascites group (25/19–30 mm/h, 20/11–25 mg/L, and 0.259/0.159–0.350 ng/mL, respectively) ($P < 0.001$, for all). Likewise, Viallon et al. [36], Such et al. [37], Papp et al. [38], and Wu et al. [39] described elevations of inflammatory mediators in the setting of SBP. This could be explained by activation of cytokine synthesis and innate immunity in response to circulating bacterial endotoxins [40].

Table 1 Demographic, clinical, and laboratory data of the studied groups

	Sterile ascites $n = 118$	SBP $n = 60$	P
Age (mean ± SD, years)	57.3 ± 7.3	57.6 ± 6.8	0.824
Male sex	55 (46.6%)	38 (63.3%)	0.073
Hypertension	12 (10.2%)	9 (15.0%)	0.345
Diabetes mellitus	18 (15.3%)	11 (18.3%)	0.599
Cause of liver disease			0.727**
- HCV infection	94 (79.7%)	51 (85.5%)	
- HBV infection	20 (16.9%)	8 (13.3%)	
- Other causes	4 (3.4%)	1 (1.7%)	
Serum albumin (mean ± SD, g/dL)	2.53 ± 0.18	2.49 ± 0.21	0.178
Serum Total bilirubin (median/IQR, mg/dL)	2.11/0.91–3.29	2.00/1.50–3.42	0.167*
INR (mean ± SD)	1.47 ± 0.20	1.53 ± 0.28	0.095
ALT (median/IQR, IU/L)	27/18–38	34/15–44	0.387*
AST (median/IQR, IU/L)	48/36–60	47/29–74	0.892*
Serum creatinine (median/IQR, mg/dL)	1.00/1.00–1.00	1.00/1.00–1.75	0.158*
Serum LDH (mean ± SD, IU/L)	214 ± 54	226 ± 51	0.126
Blood TLC (median/IQR, $\times 10^3/mm^3$)	6.10/4.00–8.00	7.00/4.43–8.90	0.158*
Hemoglobin (mean ± SD, g/dL)	10.07 ± 1.49	10.06 ± 1.33	0.952
Platelets count (median/IQR, $\times 10^3/mm^3$)	90/66–144	82/66–144	0.550*
ESR (median/IQR, mm/hour)	25/19–30	31/23–36	< 0.001*
CRP (median/IQR, mg/L)	20/11–25	27/24–29	< 0.001*
PCT (median/IQR, ng/mL)	0.259/0.159–0.350	0.691/0.604–1.690	< 0.001*
PEC index [PCT × (ESR + CRP)] (median/IQR)	9.89/5.93–15.00	41.04/31.18–92.99	< 0.001*
Ascitic fluid albumin (mean ± SD, g/dL)	0.837 ± 0.148	0.875 ± 0.128	0.094
Ascitic fluid glucose (mean ± SD, g/dL)	112 ± 17	99 ± 12	< 0.001
Ascitic fluid LDH (mean ± SD, IU/L)	109 ± 18	157 ± 42	< 0.001
Ascitic fluid PMNL (median/IQR, cell/mm^3)	200/170–207	3334/274–641	< 0.001*
Ascitic fluid PMNL ≥ 250/mm^3	0 (0.0%)	60 (100.0%)	< 0.001
Positive ascitic fluid bacterial culture	0 (0.0%)	25 (41.7%)	< 0.001

SD standard deviation, *IQR* interquartile range, *HCV* hepatitis C virus, *HBV* hepatitis B virus, *INR* international normalized ratio, *ALT* alanine aminotransferase, *AST* aspartate aminotransferase, *IU* international unit, *LDH* lactate dehydrogenase, *TLC* total leukocytic count, *ESR* erythrocyte sedimentation rate, *CRP* C-reactive protein, *PCT* procalcitonin, *PMNL* polymorphonuclear leukocytes
*Mann–Whitney *U* test, ** Fisher's exact test

As a pro-inflammatory cytokine, PCT is elevated in acute bacterial infections and reaches the highest serum level in severe infections and sepsis as it is enhanced by systemic inflammatory response. It is not elevated by viral infection or autoimmune inflammation [24–26]. Serum PCT measurement has an established role in differentiation between bacterial infections and other inflammatory conditions [25, 41]; however, its use as a diagnostic biomarker for SBP has been reported frequently in the last decade, with conflicting results [22, 27–30, 38, 39].

In this work, with the exception that CRP was more sensitive than PCT for SBP diagnosis (93.33% versus 81.67%, respectively), the sensitivity and specificity of serum PCT at a cutoff value of 0.590 ng/mL for SBP diagnosis (81.67% and 93.33%, respectively, AUC: 0.879) were relatively higher than that of ESR at a cutoff value of 27.0 mm/h (73.33% and 61.67%, respectively, AUC 0.679) and that of CRP at a cutoff value > 21.0 mg/L (93.33% and 51.67%, respectively; AUC 0.736). PCT appears to be superior in detecting septic conditions to other pro-inflammatory markers like ESR and CRP, because of its earlier increase upon infection and its better specificity [36, 38, 39, 41].

A previous meta-analysis by Yang et al. [27] including18 studies on 1827 DCPs, published between 2000 and 2014, investigated the diagnostic performance of PCT as a marker of SBP. They reported a relatively good diagnostic performance with a summary estimate of sensitivity and specificity of 83.0% and 92.0%, respectively,

Table 2 Comparison between culture-positive and culture-negative SBP patients, regarding serum and AF biomarkers

	Culture negative $n = 35$	Culture-positive $n = 25$	P
ALT (median/IQR, IU/L)	38/15–45	26/15–39	0.413*
AST (median/IQR, IU/L)	44/31–74	48/22–79	0.554*
Serum LDH (mean ± SD, IU/L)	225 ± 46	229 ± 58	0.750
Blood TLC (median/IQR, × 10^3/mm3)	7.0/4.8–9.0	7.0/4.3–8.6	0.553*
Platelets count (median/IQR, × 10^3/mm^3)	82/66–145	80/68–133	0.887*
ESR (median/IQR, mm/hour)	32/22–36	30/28–35	0.952*
CRP (median/IQR, mg/L)	26/24–28	27/25–30	0.253
PCT (median/IQR, ng/mL)	0.614/0.410–0.649	1.733/1.256–2.500	< 0.001*
PEC index [PCT × (ESR + CRP)] (median/IQR)	36.34/25.22–40.19	101.48/70.79–136.89	< 0.001*
Ascitic fluid albumin (mean ± SD, g/dL)	0.865 ± 0.13	0.889 ± 0.13	0.467
Ascitic fluid glucose (mean ± SD, g/dL)	104 ± 9	93 ± 13	< 0.001
Ascitic fluid LDH (mean ± SD, IU/L)	142 ± 28	177 ± 50	< 0.001
Ascitic fluid PMNL (median/IQR, cell/mm^3)	275/260–310	655/463–6700	< 0.001*

SD standard deviation, *IQR* interquartile range, *ALT* alanine aminotransferase, *AST* aspartate aminotransferase, *LDH* lactate dehydrogenase, *TLC* total leukocytic count, *ESR* erythrocyte sedimentation rate, *CRP* C-reactive protein, *PCT* procalcitonin, *PMNL* polymorphonuclear leukocytes
*Mann–Whitney *U* test

which came very close to our results. On the other hand, Lesińska et al. [22] reported that serum PCT could not distinguish patients with and without SBP. The small sample size (n = 32) of their study [22] could explain this contradictory result.

Positive results of AF bacterial cultures, in this study, were found only in 41.6% (25/60) of SBP patients. Nearly the same result was frequently reported before [12, 14, 15]. The predominance of gram-negative over gram-positive bacteria among culture positive cases, in our study, goes with other studies [1, 42]. In the current work, serum PCT, opposite to ESR and CRP, was significantly elevated in culture positive cases of SBP (P < 0.001). This comes in accordance with the study of Cekin et al. [43], but it does not come in agreement with the studies of EL-Gendy et al. [44] or Cai et al. [28] who reported the lack of sensitivity of serum PCT to differentiate the culture results in SBP patients.

In this research, the newly advocated PEC index [calculated as PCT × (ESR + CRP)] was significantly higher in SBP group than in sterile ascites group (P < 0.001),

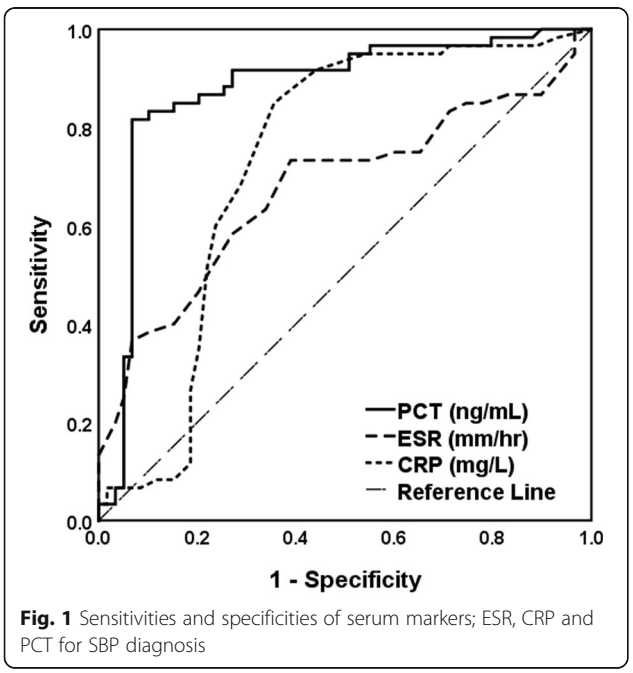

Fig. 1 Sensitivities and specificities of serum markers; ESR, CRP and PCT for SBP diagnosis

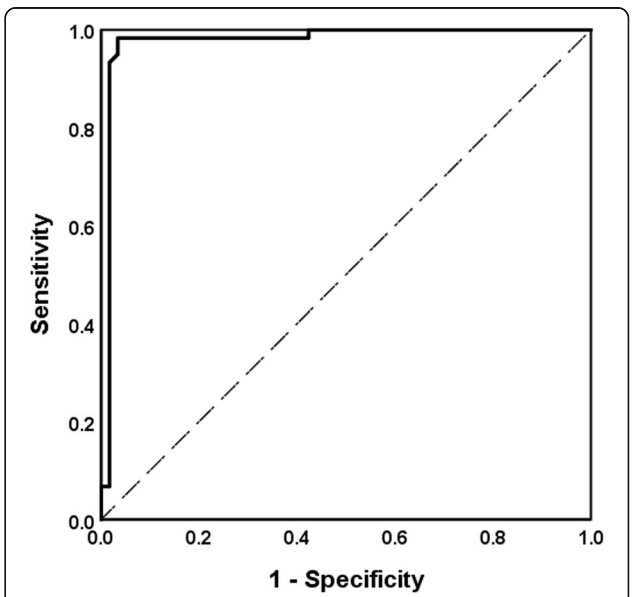

Fig. 2 Sensitivity and specificity of serum PEC index for SBP diagnosis

Table 3 Diagnostic accuracy of PEC index and its components for SBP diagnosis and for distinguishing culture-negative SBP from sterile ascites, using ROC statistics

Serum markers	SBP diagnosis					Discrimination between culture-negative SBP and sterile ascites				
	Cutoff value	Sensitivity	Specificity	AUC (95% CI)	*P*	Cutoff value	Sensitivity	Specificity	AUC (95% CI)	*P*
PCT ng/mL	> 0.590	81.67%	93.33%	0.879 0.809–0.948	*< 0.001*	> 0.305	85.70%	72.90%	0.825 0.742–0.907	*< 0.001*
ESR mm/hour	> 27.0	73.33%	61.67%	0.679 0.581–0.776	*< 0.001*	> 27.0	68.60%	61.00%	0.649 0.521–0.776	*0.008*
CRP mg/L	> 21.0	93.33%	51.67%	0.736 0.639–0.833	*< 0.001*	> 23.5	80.00%	64.40%	0.704 0.613–0.794	*< 0.001*
PEC index	> 20.0	98.33%	96.67%	0.977 0.940–0.996	*< 0.001*	> 20.0	97.10%	96.60%	0.970 0.934–1.0	*< 0.001*

ROC receiver operating characteristic, *PCT* procalcitonin, *ESR* erythrocyte sedimentation rate, *CRP* C-reactive protein, *AUC* area under the curve, *CI* confidence interval

and it was significantly more elevated in culture-positive than in culture-negative cases of SBP ($P < 0.001$).

In the present study, at a cutoff value of 20, the sensitivity and specificity of serum PEC index for SBP diagnosis (98.33% and 96.67%, respectively, AUC 0.977) were much higher than that of serum PCT, ESR, and CRP. Likewise, the sensitivity and specificity of serum PEC index, at a cutoff value of 20, to distinguish cases with culture-negative SBP from sterile ascites cases (97.1% and 96.6%, respectively, AUC 0.970), were much better than that of PEC components. The superiority of PEC index over any of its components, for diagnosis of SBP and even of its culture-negative subtype, could be explained simply by the mathematical compensatory effect of combining several markers with different degrees of sensitivity and specificity, helping escaping false positive and false negative results.

Furthermore, the above mentioned diagnostic accuracy of PEC index in SBP is better than that of other promising serum markers that were reported in the last few years [32, 33]. Although serum homocysteine had relatively high sensitivity and specificity for distinguishing SBP (95.1% and 89.3%, respectively; AUC 0.932) [32], it is less accurate than PEC index. A D-dimer cutoff value of 1500 ng/mL was determined optimal for ruling out SBP due to high sensitivity (96.8%); however, this marker was not useful for confirming SBP due to low specificity (40.6%) [33].

Similar to our study design, Wang et al. [45] have conducted a recently published study on 259 consecutive cirrhotic patients with ascites admitted to a Chinese

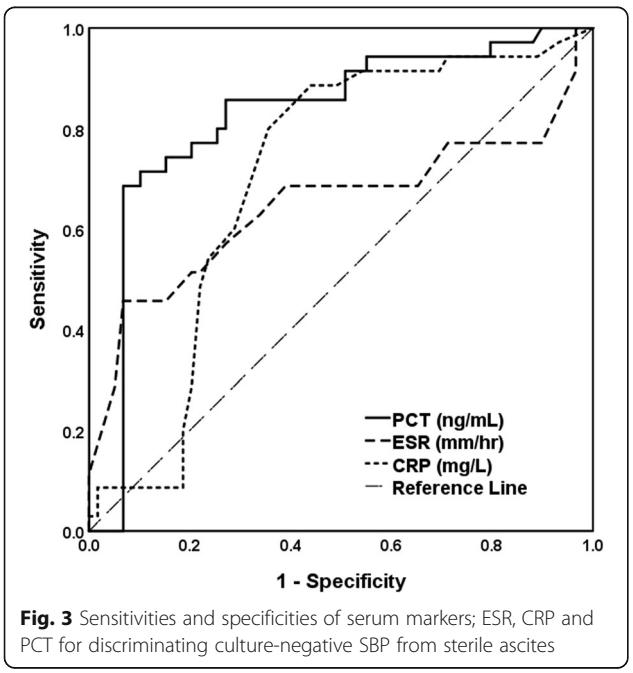

Fig. 3 Sensitivities and specificities of serum markers; ESR, CRP and PCT for discriminating culture-negative SBP from sterile ascites

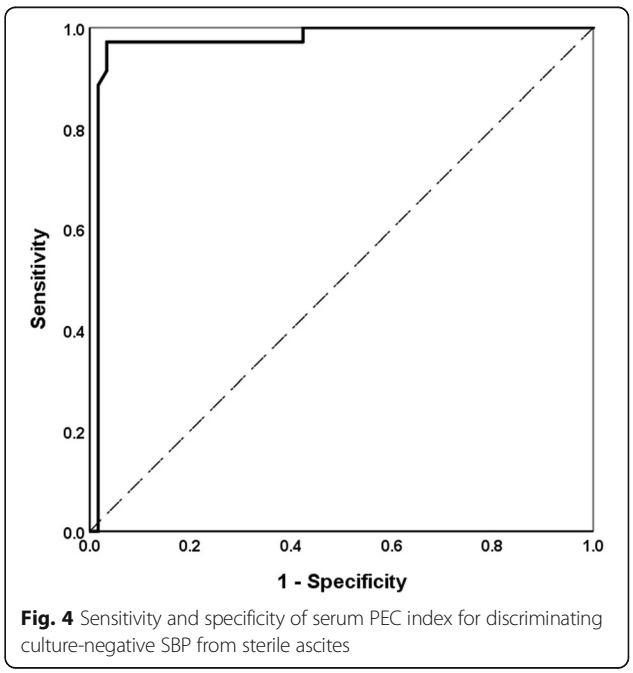

Fig. 4 Sensitivity and specificity of serum PEC index for discriminating culture-negative SBP from sterile ascites

military hospital to investigate the efficacy in SBP diagnosis of combined measurement of PCT, mean fluorescence intensity of mature neutrophils (sNFI) and difference in hemoglobin concentration between newly formed and mature red blood cells (dCHC). Of these, 51/259 (19.7%) had culture-positive SBP, 58/259 (22.4%) had culture-negative SBP, and 150/259 (57.9%) had sterile ascites. The total bioscore of those three markers used by Wang et al. [45], at a cutoff value of ≥3.40, had a sensitivity of 92.6%, a specificity of 95.3% and an AUC of 0.937 (95% CI 0.901–0.994, $P < 0.001$), which are less than that of PEC index innovated in our study.

Some limitations to our study are to be mentioned. First is the relatively small sample size. Second, we did not test for serum markers other than PEC index components to help making head to head comparison. Finally, it would have been more appropriate if we added one more group of DCPs with infections other than SBP to assess specificity of PEC index for SBP.

Conclusion

The novel serum PEC index seems sufficient to make a fairly accurate non-invasive diagnosis of SBP in cirrhotic patients with ascites, provided that non-SBP bacterial infections are excluded.

Recommendations

To validate the clinical use of serum PEC index for SBP diagnosis, further larger trials are needed that should involve assessment of PEC index in non-SBP infections and its comparison with other serum biomarkers.

Abbreviations

AF: Ascitic fluid; AUC: Area under the curve; CRP: C-reactive protein; DCPs: Decompensated cirrhotic patients; ESR: Erythrocyte sedimentation rate; PCT: Procalcitonin; PEC index: Index of combined measurement of PCT, ESR and PCT; PMNL: Polymorphonuclear leukocytes; ROC: Receiver operating characteristic; SBP: Spontaneous bacterial peritonitis

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Authors' contributions

HE had selected the idea and design of the work, had contributed in the data collection and interpretation, shared in drafting the work, and had made the final revision of data. SE had contributed in the data collection and interpretation and shared in drafting the work. AM had helped in the data collection and analysis and had performed the laboratory work. All authors have read and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to confidential and institutional ethical issues but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study was conducted in accordance with the ethical principles of the 1975 Declaration of Helsinki, and it was reviewed and approved by Research Ethics Committee of Faculty of Medicine, Zagazig University Institutional Review Board, #5644, in 9 March 2019. A written informed consent was obtained from all the participants after explaining the aim and concerns of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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