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Serum procalcitonin as a prognostic marker in sepsis and its correlation with SOFA score: An observational study

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Abstract

Introduction: Sepsis is a life-threatening condition characterized by a dysregulated host response to infection, resulting in acute organ dysfunction. Serum procalcitonin (PCT), a peptide precursor of calcitonin, has emerged as a promising biomarker in the diagnosis and prognostication of sepsis. This study aimed to evaluate serum PCT concentrations in relation to the severity of organ dysfunction in sepsis and to assess its role as an early prognostic indicator of clinical outcome.

Materials and methods: This hospital-based prospective observational study was conducted in the Department of Medicine, Silchar Medical College and Hospital, Assam, from June 2021 to May 2022. A total of 100 patients diagnosed with sepsis, fulfilling the inclusion and exclusion criteria, were enrolled. For each patient, serum PCT levels and Sequential Organ Failure Assessment (SOFA) scores were recorded on admission.

Results: Mean serum PCT levels were significantly higher among patients with severe organ dysfunction or higher SOFA scores compared to those with milder dysfunction ($p < 0.001$). A strong positive correlation was observed between serum PCT and SOFA scores ($r = 0.479$, $p < 0.001$). Elevated PCT levels were associated with increased disease severity, multi-organ dysfunction, and higher mortality.

Conclusion: Serum procalcitonin is a reliable prognostic biomarker in sepsis. Its positive correlation with SOFA scores reflects disease severity and the extent of organ dysfunction, supporting its role in early risk stratification and prognostication.

Keywords: sepsis; procalcitonin; SOFA score; organ dysfunction; mortality

Introduction

Sepsis is a life-threatening organ dysfunction resulting from a dysregulated host response to infection [1]. It remains a major cause of morbidity and mortality worldwide [2]. According to the World Health Organization, an estimated 48.9 million cases of sepsis and 11 million related deaths occurred globally in 2017, accounting for more than 20% of all deaths [3]. Sepsis and severe sepsis are associated with high in-hospital mortality among adult patients, ranging from 23% to 39% [4,5]. Despite advances in medical care, sepsis continues to be the second most common cause of mortality in intensive care units (ICUs) [6]. Early identification of patients at risk of poor outcomes and optimization of clinical decision-making remain essential to improving survival [7].

The updated "Sepsis-3" clinical criteria define sepsis as a suspected or confirmed infection accompanied by acute organ dysfunction, indicated by an increase of two or more points from baseline in the Sequential (Sepsis-related) Organ Failure Assessment (SOFA) score. The SOFA score has long been utilized to quantify organ dysfunction, with higher scores correlating strongly with increased mortality. Septic shock is recognized as a subset of sepsis characterized by profound circulatory, cellular, and metabolic abnormalities that substantially elevate mortality risk. Diagnostic criteria for septic

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shock include sepsis with the need for vasopressor therapy to maintain a mean arterial pressure ≥65 mmHg and a serum lactate concentration >2.0 mmol/L, despite adequate fluid resuscitation [8].

Procalcitonin (PCT), a 116-amino-acid peptide precursor of the hormone calcitonin involved in calcium homeostasis, is normally present in very low serum concentrations (0.1–0.5 ng/mL). It serves as an inflammatory biomarker useful in detecting bacterial, fungal, and parasitic infections [9–13]. Serum PCT levels rise markedly in bacterial infections, particularly sepsis, but remain low in viral infections, non-infectious inflammatory conditions, and localized infections. Clinically, PCT helps differentiate bacterial sepsis from the systemic inflammatory response syndrome (SIRS) of non-bacterial origin—such as that associated with viral infections, burns, acute pancreatitis, or cardiogenic shock—where conventional markers like C-reactive protein (CRP) may be elevated [9–13]. Moreover, PCT plays a pivotal role in guiding antibiotic therapy and promoting antibiotic stewardship.

Therefore, PCT has emerged as a promising biomarker for the early diagnosis, risk stratification, and management of sepsis and septic shock. Monitoring novel biomarkers such as PCT in conjunction with conventional inflammatory markers may enhance diagnostic accuracy and prognostic assessment [14].

Given the correlation between elevated serum PCT concentrations and adverse outcomes in sepsis, the present study was undertaken to evaluate serum PCT levels in relation to the severity of organ dysfunction and to assess its utility as an early prognostic marker in predicting clinical outcomes among patients with sepsis.

Materials and methods

This hospital-based prospective observational study was conducted in the Department of Medicine, Silchar Medical College and Hospital, Silchar, Assam, over a period of one year, from June 2021 to May 2022. A total of 100 patients diagnosed with sepsis were enrolled after satisfying the inclusion and exclusion criteria. Ethical approval was obtained from the Institutional Ethical Committee.

Patients presenting to the outpatient or inpatient departments with clinical features suggestive of sepsis—such as tachypnoea, tachycardia, hypotension, altered mentation, and the presence of an identifiable infectious focus—were evaluated and screened for eligibility. The quick Sequential Organ Failure Assessment (qSOFA) score was used as a bedside tool to identify patients at risk for sepsis. Individuals with a qSOFA score ≥2 were considered to be at high risk. Routine laboratory investigations, including complete blood count, liver and renal function tests, urine examination, arterial blood gas analysis, and blood culture, were performed in all patients. Additional diagnostic tests such as electrocardiography,chestradiography,ultrasonography, and computed tomography (CT) scans of the abdomen or thorax were performed when required to localize the source of infection. In selected cases, cerebrospinal fluid (CSF), ascitic fluid, pleural fluid, urine, and pus samples were analyzed and cultured for microbiological evaluation.

Sepsis was diagnosed using the Sequential Organ Failure Assessment (SOFA) score, with a score of ≥2 points consequent to infection being diagnostic of sepsis. The SOFA score was calculated on day 1 of admission, incorporating platelet count, bilirubin, creatinine, mean arterial pressure, Glasgow Coma Scale (GCS) score, and the ratio of arterial oxygen tension to fractional inspired oxygen (PaO_2/FiO_2). The severity of organ dysfunction was graded according to the SOFA score: Group 1 (0–6), Group 2 (7–12), Group 3 (13–18), and Group 4 (19–24). Serum procalcitonin (PCT) levels were measured on day 1 for all patients.

Comparisons of serum PCT concentrations were made across the four groups to assess the relationship between PCT levels and the severity of organ dysfunction. Correlations between serum PCT levels, SOFA scores, and clinical outcomes (including mortality) were analyzed. Statistical analysis was performed using Microsoft Excel, GraphPad Prism, and IBM SPSS software version 21. A p-value of <0.05 was considered statistically significant.

Inclusion criteria: Patients aged above 18 years who were clinically diagnosed with sepsis, as defined by the Sepsis-3 criteria (SOFA score ≥2 in the presence of infection), were included in the study. All eligible participants were evaluated upon hospital admission, and relevant clinical, biochemical, and microbiological data were collected for analysis.

Exclusion criteria: Patients aged 18 years or below were excluded from the study. Individuals with post-operative or post-traumatic sepsis, pre-existing thyroid disorders that could affect serum procalcitonin (PCT) levels, autoimmune diseases, chronic kidney disease, or liver disease such as acute or chronic hepatitis and cirrhosis were also excluded. Additional exclusion criteria included patients with pancreatitis or burns, immunocompromised individuals such as those with malignancy, HIV infection, or receiving chemotherapy or immunosuppressive therapy, and those who had received oral antibiotics within the preceding 28 days or parenteral antibiotics within the past 7 days.

Table 1: Sequential Organ Failure Assessment (SOFA) Score [20].

System	*Score*				
	0	*1*	*2*	*3*	*4*
Respiration					
PaO2/FiO2 (mmHg)	≥400	<400	<300	<200 with respiratory support	<100 with respiratory support
Coagulation					
Platelets (×10^3/μL)	≥150	<150	<100	<50	<20
Liver					
Bilirubin(mg/dL)	<1.2	1.2-1.9	2.0-5.9	6.0-11.9	>12
Cardiovascular					
Mean arterial pressure(mmHg)	≥70mmHg	<70mmHg	Dopamine<5 or dobutamine (any dose)	Dopamine 5.1-15 or Epinephrine ≤0.1 or Norepinephrine ≤0.1	Dopamine >15 or Epinephrine >0.1 or Norepinephrine >0.1
Central nervous system					
GCS score	15	13-14	10-12	6-9	<6
Renal					
Creatinine (mg/dL)	<1.2	1.2-1.9	2.0-3.4	3.5-4.9	>5.0
Urine output(mL/day)				<500	<200

Abbreviations: FIO_2, fraction of inspired oxygen; MAP, mean arterial pressure; PaO_2,partial pressure of oxygen

Results

Demographic profile of the study population

The mean age of the study population was 54.2 ± 16.29 years. The majority of patients (24%) belonged to the 60–69 years age group, followed by 20% in the 50–59 years age group, while the smallest proportion (8%) were aged 80 years and above. Of the 100 patients included in the study, 56 were males and 44 were females, yielding a male-to-female ratio of 1.2:1. The most common comorbid condition was Type 2 Diabetes Mellitus (38%), followed by Hypertension (28%). The mean serum procalcitonin (PCT) concentration in the overall study population was 22.2 ± 24.67 ng/mL, as summarized in Table 2.

Table 2: Basic characteristics of the study population.

Characteristic	*N (%)*
Males	56 (56%)
Females	44 (44%)
Mean age (years)	54.20±16.290
Hypertension	28 (28%)
Diabetes mellitus	38 (38%)
Mean PCT (ng/ml)	22.2±24.67

Etiology of sepsis and cause of death

Pneumonia (40%) was the most common underlying cause of sepsis, followed by urinary tract infection (UTI) (27%) and acute gastroenteritis (12%). Among the 100 patients with sepsis, there were 24 in-hospital deaths (24%). Pneumonia (58.3%) and UTI (29.1%) were the leading causes of mortality, as presented in Table 3.

Table 3: Distribution of cases according to aetiology of sepsis and cause of death.

Infection	*Frequency (n=100)*	*No of death (n=24)*
Pneumonia	40 (40%)	14 (58.3%)
Urinary tract infection	27 (27%)	7 (29.1%)
Acute gastroenteritis	12 (12%)	1 (4.1%)
Pyogenic/viral meningitis	8 (8%)	1 (4.1%)
Cellulitis	2 (2%)	0 (0%)
Pyelonephritis	3 (3%)	0 (0%)
Psoas abscess	4 (4%)	0 (0%)
Splenic/ liver abscess	3 (3%)	0 (0%)
SBP/ peritonitis	1 (!%)	1 (4.1%)

SOFA score and serum procalcitonin

The Sequential Organ Failure Assessment (SOFA) score was calculated for each patient with sepsis and categorized into four groups based on the total score. Among the 100 patients studied, the majority belonged to SOFA group 1 (44%), followed by group 2 (40%), group 3 (14%), and group 4 (2%). The mean serum

procalcitonin (PCT) concentration in SOFA group 1 was 8.14 ± 7.2 ng/mL, whereas in SOFA group 4, it was markedly elevated at 86.75 ± 0.35 ng/mL. A statistically significant positive correlation was observed between serum PCT levels and SOFA scores ($p < 0.001$), indicating that higher PCT concentrations were associated with greater severity of organ dysfunction, as shown in Table 4.

Table 4: SOFA groups and mean serum PCT concentrations.

SOFA Score (Day 1)	*Number of patients (n=100)*	*Percentage (100%)*	*Mean serum Procalcitonin (ng/ml)*	*P value*
Group 1 (0-6)	44	44%	8.14±7.2	
Group 2 (7-12)	40	40%	28.7±29.59	
Group 3 (13-18)	14	14%	38.57±10.38	<0.001*
Group 4 (19-24)	2	2%	86.75±0.35	

SOFA groups and distribution of patients

Among the 44 patients in SOFA group 1, an equal gender distribution was observed, with 50% males and 50% females, whereas in SOFA group 4, all patients were female. Regarding age distribution, 50% of patients in SOFA group 1 were aged below 60 years, while the remaining 50% were above 60 years. In contrast, all patients in SOFA group 4 (100%) were above 60 years of age. Among the patients in SOFA group 1, 36.4% had diabetes mellitus and 31.8% had hypertension. Notably, in SOFA group 4, none of the patients had diabetes or hypertension. These findings are summarized in Table 5.

Table 5: SOFA groups and distribution of patients.

Risk factors	*n*	*SOFA Group 1 (n=44)*	*SOFA Group 2 (n=40)*	*SOFA Group 3 (n= 14)*	*SOFA Group 4 (n=2)*
Gender					
Male	56	22(50%)	26(65%)	8(57.1%)	0(0%)
Female	44	22(50%)	14(35%)	6(42.9%)	2(100%)
Age (years)					
<60	58	22(50%)	32(80%)	4(29%)	0(0%)
≥60	42	22(50%)	8(20%)	10(71%)	2(100%)
Hypertension					
Hypertensive	28	14(31.8%)	12(30%)	2(14.3%)	0(0%)
Non-hypertensive	72	30(68.2%)	28(70%)	12(85.7%)	2(100%)
Diabetes mellitus					
Diabetic	38	16(36.4%)	14(35%)	8(57.1%)	0(0%)
Non-Diabetic	62	28(63.6%)	26(65%)	6(42.9%)	2(100%)

Comparison of study variables according to organ dysfunction (SOFA Groups)

The mean Glasgow Coma Scale (GCS) score, mean arterial pressure (MAP), platelet count, and PaO_2/FiO_2 ratio were significantly lower in SOFA groups 3 and 4 compared to SOFA groups 1 and 2, indicating progressive deterioration in organ function with increasing SOFA scores. Conversely, mean serum procalcitonin (PCT) levels showed a significant rise in higher SOFA groups (3 and 4) compared to lower groups (1 and 2) ($p < 0.001$). Among the 44 patients in SOFA group 1, only 22.7% required inotropic support, whereas all patients in SOFA group 4 (100%) required both inotropic and mechanical ventilation support. The mortality rate increased proportionally with the severity of organ dysfunction, being highest in SOFA group 4 (100%) and lowest in SOFA group 1 (9.1%) (Table 6).

Correlation between study variables

There was a significant positive correlation between serum PCT levels and SOFA scores (Spearman's rho, $r=479$, $p<0.001$), implying that higher SOFA score (indicating degree of organ dysfunction) was associated with increased PCT levels. In our study, we also found a

statistically significant (p < 0.001) negative correlation between mean SOFA score and the study variables GCS, PaO2/FiO2, Mean arterial pressure and platelet count (r= -0.560, -0.414, -0.283, -0.518 respectively). No significant correlation was found between serum PCT and length of hospitalisation (Table 7).

Table 6: Comparison of study variables according to organ dysfunction (SOFA group)

Variables	*SOFA Group 1 (n=44)*	*SOFA Group 2 (n=40)*	*SOFA Group 3 (n=14)*	*SOFA Group 4 (n=2)*	*p value*
Age(years)	55.09±16.67	49.9±16.4	62.29±12.23	64±1.41	0.067
Mean GCS score	14.82±0.50	14.28±1.89	10.79±3.60	6.50±0.71	<0.001
Mean arterial pressure (mmHg)	85.15±14.61	80.43±7.98	75.24±5.18	73.3±0.01	0.019
S. creatinine (mg/dl)	2.19±0.62	2.54±0.64	2.51±0.63	2.33±0.13	0.066
Total bilirubin (mg/dl)	2.16±1.04	2.8±1.26	2.24±0.54	2.29±0.04	0.054
Platelet count (lakhs/ mm3)	212857.3±121241.6	118382.3±43683.8	94380±26808.3	45750±353.6	<0.001*
PaO2/FiO2	317.65±109.6	240.36±112.3	176.5±95.4	139.0±25.6	<0.001*
SOFA score	4.23±1.4	8.4±1.96	15.57±1.65	20.5±0.71	<0.001*
Mean PCT (ng/ml)	8.14±7.2	28.7±29.59	38.57±10.38	86.75±0.35	<0.001*
Duration of hospital stay	5.98±3.08	7.85±3.95	8.5±5.59	8.5±0.71	0.067
Septic shock (MAP < 70mm Hg) requiring ionotropic support	10 (22.7%)	25(62.5%)	13(92.9%)	2(100%)	<0.001*
Mechanical ventilation	0(0%)	1(2.5%)	1(7.1%)	2(100%)	<0.001*
Mortality	4(9.1%)	10(25%)	8(57.1%)	2(100%)	<0.001*

Table 7: Pearson correlation between study variables.

Correlation between study variables	*r value*	*P value*
SOFA score Vs S. Procalcitonin	0.479	<0.001
SOFA score Vs GCS	-0.560	<0.001
SOFA score Vs PaO2/FiO2	-0.414	<0.001
SOFA score Vs S. creatinine	0.149	0.139
SOFA score Vs Total bilirubin	0.113	0.263
SOFA score Vs Platelet count	-0.518	<0.001
SOFA score Vs MAP	-0.283	<0.001
Serum procalcitonin Vs Length of hospital stay	0.075	0.456

Comparison of study variables according to outcome

Mean PCT level in persons who survived was 16.24±21.1 ng/ml, while it was significantly higher in persons who died (41.06±26.06 ng/ml) (p value <0.001). Similarly, mean SOFA score was significantly higher in non-survivors compared to survivors (p<0.001), whereas mean GCS, mean PaO2/FiO2, mean platelet count and mean arterial pressure (MAP) were significantly lower in non-survivors compared to survivors. (p value <0.05 in all four). Our study also showed a higher mortality rate among female patients compared to male patients (66.6% vs 33.3%, p-value 0.010) (Table 8).

Discussion

In the present study, the majority of sepsis cases (24%) occurred in the 60–69-year age group, with a mean age of 54.20 ± 16.29 years. This finding is comparable to studies conducted by Patil et al. (57.39 ± 16.10 years) [15], Ryu et al. (62 years) [16], and Jain et al. (50.7 ± 18.7 years) [17]. The mean age among survivors was 52.47 ± 17.08 years, while that of non-survivors was 59.67 ± 12.26 years; however, this difference was not statistically significant (p = 0.059), consistent with the findings of Jain et al. [17].

A male predominance was observed in our study, with 56% males and 44% females, yielding a male-to-female ratio of 1.2:1. Among survivors, 63.1% were males and 36.8% females, while mortality was higher among females (66.6%) than males (33.3%), and this difference was statistically significant (p = 0.010). Similar male preponderance was reported by Patil HV et al. [15] and Jain et al. [17]. The higher prevalence of sepsis in males may be attributed to greater production of inflammatory

mediators such as TNF-α, IL-1, and IL-6, whereas females have higher levels of the immunoprotective hormone oestradiol [18]. Additionally, sociocultural factors and healthcare access disparities in our setting may contribute, as males are often prioritized for hospital admission and intensive care.

Table 8: Comparison of study variables according to outcome.

Variables	*Mean (n=100)*	*Survivor (n=76)*	*Non-survivor (n= 24)*	*p value*
Age(years)	54.2±16.29	52.47±17.08	59.67±12.26	0.059
Sex	Male-56(56%) Female-44(44%)	Male-48(63.2%) Female-28(36.8%)	Male-8(33.3%) Female-16(66.6%)	0.010
Serum Procalcitonin (ng/ml)	22.2±24.67	16.24±21.1	41.06±26.06	<0.001
SOFA score	7.81±4.51	6.71±3.55	11.29±5.47	<0.001
GCS score	13.87±2.48	14.30±2.15	12.50±2.96	0.002
Mean arterial pressure (mm Hg)	81.64±11.6	83.19±12.31	76.72±7.22	0.016
PaO2/FiO2	263.39±119.70	280.83±119.61	208.18±104.09	0.009
S. creatinine (mg/dl)	2.38±064	2.31±0.63	2.60±0.68	0.054
Total bilirubin (mg/dl)	2.43±1.11	2.41±1.12	2.51±1.08	0.713
Platelet count (lakhs/$mm^{3)}$	155138.3±100105. 2	167571.7±103951. 2	115765.8±75955. 5	0.026
Length of hospitalization (days)	7.13±3.93	7.53±4.23	5.88±2.46	0.073

Pneumonia was the most common infection leading to sepsis (40%), followed by urinary tract infection (27%) and acute gastroenteritis (12%). These findings are consistent with studies by Angus et al. [19] and Vincent et al. [20], who reported respiratory infections as the predominant source of sepsis, followed by genitourinary and abdominal infections. Type 2 diabetes mellitus (38%) and hypertension (28%) were the most frequent comorbidities among patients with sepsis in our cohort.

In this study, mean serum procalcitonin (PCT) concentrations were significantly higher among patients with severe organ dysfunction or higher SOFA scores (groups 3 and 4) than those with milder dysfunction (groups 1 and 2) ($p < 0.001$). Similar findings were observed by Castelli et al. [21] and Wang et al. [22]. A significant positive correlation between serum PCT levels and SOFA scores ($r = 0.479$, $p < 0.001$) was also found, in agreement with reports by Huang et al. [23], Patil et al. [15], and Wang et al. [22]. This correlation suggests that as organ dysfunction worsens, reflected by increasing SOFA scores, serum PCT levels rise correspondingly, indicating the severity of sepsis and extent of end-organ injury.

Furthermore, the mean SOFA score and serum PCT concentration were higher among non-survivors (11.29 ± 5.47 and 41.06 ± 26.06 ng/ml, respectively) compared to survivors (6.71 ± 3.55 and 16.24 ± 21.1 ng/ml, respectively), and this difference was statistically significant ($p < 0.001$). These results are consistent with studies by Tanriverdi et al. [24] and Qin X et al. [25], which also demonstrated higher PCT levels and SOFA scores among non-survivors. The mean duration of hospital stay was slightly longer among survivors (7.5 ± 4.2 days) compared to non-survivors (5.8 ± 2.4 days), although the difference was not statistically significant. No significant correlation was found between serum PCT levels and duration of hospitalization ($r = 0.075$, $p = 0.456$).

Limitations: This was a single-centre study with a relatively small sample size, particularly in patients with severe organ dysfunction (SOFA groups 3 and 4), which limits the generalizability of the findings. Only baseline procalcitonin levels were assessed; serial measurements could have provided stronger insights into disease progression, therapeutic response, and prognostic value.

Conclusion

Serum procalcitonin (PCT) serves as a valuable prognostic biomarker in sepsis, showing a strong positive correlation with the Sequential Organ Failure Assessment (SOFA) score. Elevated PCT levels are closely associated with increased disease severity, greater organ dysfunction, and higher mortality. As a reliable biochemical indicator, PCT complements the SOFA score in assessing the extent of organ failure, facilitating early identification of high-risk patients, timely therapeutic intervention, and improved prognostic stratification in sepsis management.

Conflicts of interest

Authors declare no conflict of interest.

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