

Procalcitonin as a predictor of prognosis in patients with bacteremia admitted to the intensive care unit

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ABSTRACT

Background: The study aimed to determine the association between procalcitonin levels and clinical outcomes in patients with bacteremia admitted to the intensive care unit and to compare procalcitonin levels between community-acquired and hospital-acquired bacteremia.

Material and Methods: A prospective observational longitudinal study was conducted from 1st September 2025 to 28th February 2026 in the adult intensive care units of Mem on Medical Institute Hospital, Karachi. Using consecutive sampling, a total of 199 adult patients with proven bacteremia were enrolled. The Roche Cobas e411 ECLIA platform was used to measure procalcitonin levels at admission, day 5, and day 10. Hospital mortality was the primary outcome. Data were analyzed using SPSS version 26.

Results: Among 199 ICU patients with bacteremia, the median age was 53.5 years, and 59.3% were male; sepsis was the most common diagnosis (31.2%). Median procalcitonin (PCT) levels declined from 8.90 ng/mL at baseline to 5.70 and 3.60 ng/mL on days 5 and 10, respectively. PCT levels were significantly higher in hospital-acquired than community-acquired bacteremia at all three time points ($p \leq 0.009$). Baseline PCT was highest among non-survivors (14.80 ng/mL), compared with survivors (6.40 ng/mL) and patients leaving against medical advice (9.60 ng/mL). Mortality increased significantly with rising PCT levels, from 7.5% for PCT 10 ng/mL ($p < 0.001$).

Conclusion: Higher baseline procalcitonin levels were significantly associated with mortality among ICU patients with bacteremia. Procalcitonin levels were also significantly higher in patients with hospital-acquired bacteremia compared with those with community-acquired bacteremia.

Keywords: Bacteremia, Hospital-acquired bacteremia, Intensive care unit, Mortality, Procalcitonin, Prognosis.

BACKGROUND

Bacteremia is defined as the presence of viable bacteria in the bloodstream and is commonly diagnosed through blood culture testing. It remains a significant cause of morbidity and mortality worldwide despite advances in antimicrobial therapy and diagnostic techniques.¹ The reported annual incidence of community-onset bacteremia ranges from 40 to 154 cases per 100,000 population, and its frequency continues to increase due to changing population demographics, increased healthcare exposure, and a growing prevalence of comorbid conditions.^{2,3} Management of bacteremia is

challenging because timely initiation of appropriate antimicrobial therapy is essential, while definitive microbiological diagnosis may require several days.⁴ Early recognition of severe infection and prompt treatment are crucial determinants of patient outcomes, particularly among critically ill patients admitted to intensive care units (ICUs). Delayed diagnosis and inappropriate antimicrobial therapy have been associated with increased mortality and prolonged hospital stay.⁵⁻⁸

Although blood culture remains the reference standard for confirmation of bacteremia, the yield of this test can change depending on variables such as prior administration of antibiotics, time of blood collection, volume of blood collected, and intermittent bacteremia. In addition, traditional blood culture methods take about 48–72 hours for identification of the cultured organisms and antimicrobial susceptibility testing, often delaying targeted antimicrobial therapy. Thus, there is the need for other biomarkers to help in early risk stratification of critically ill patients for prognostic assessment.⁹⁻¹⁰ The biomarker procalcitonin (PCT) is a polypeptide precursor of calcitonin, which is produced ubiquitously

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by parenchymal cells in response to inflammatory cytokines with a rapid rise in the setting of bacterial infection.⁸ In many adult studies, it's been well established that higher PCT concentration is associated with isolation of typical bacterial organisms especially, in relation to bacteremia due to Community acquired pneumonia.¹¹⁻¹²

Differentiating community-acquired from hospital-acquired bacteremia may help guide empirical antimicrobial selection and risk stratification. Therefore, this study aimed to compare serial PCT levels between the two groups and evaluate PCT as a prognostic marker.

MATERIAL AND METHODS

This prospective observational longitudinal study was conducted over a period of six months, from 1st September 2025 to 28th February 2026, in the adult intensive care units of Memon Medical Institute Hospital, Karachi. The study was approved by the Institutional Review Board of Memon Medical Institute Hospital (IRB/MMIH/2024/51 dated 7th November 2024) and the College of Physicians and Surgeons Pakistan. Written informed consent was obtained from all participants before enrolment. A non-probability consecutive sampling technique was used and a total of 199 adult patients with bacteremia were included. The sample size was determined using a diagnostic accuracy approach as proposed by Wan Nor Arifin. Previously reported diagnostic performance parameters for procalcitonin, including 35% sensitivity, 83% specificity, 95% confidence level and 10% absolute precision, were considered. The calculated sample size was subsequently adjusted to ensure an adequate number of participants for assessing the association between baseline procalcitonin levels and hospital mortality. A total of 199 patients meeting the eligibility criteria were therefore enrolled. Patients aged ≥ 18 years who were admitted to the adult intensive care unit with community-acquired or hospital-acquired bacteremia were eligible for inclusion. Patients who were terminally ill, had malignancy with associated infection, or had partially treated sepsis transferred from another adult intensive care unit were excluded. Community-acquired bacteremia was defined as bacteremia identified within 48 hours of hospital admission in the absence of prior healthcare exposure. Hospital-acquired bacteremia was defined as

bacteremia occurring after 48 hours of hospital admission or in patients with recent healthcare exposure, hospitalization, invasive procedures, or other relevant healthcare-associated risk factors.

The primary outcome was hospital mortality. Patient outcomes were recorded as alive, deceased, or left against medical advice (LAMA) at the end of the hospital admission. A predesigned data collection proforma was used to record demographic characteristics, primary diagnosis, comorbidities, microbiological findings, procalcitonin levels, ICU length of stay and clinical outcomes.

Serum procalcitonin levels were measured at ICU admission (baseline), day 5 and day 10. Blood samples were collected at these predefined time points. Procalcitonin was measured using the Roche Cobas e411 analyzer (Roche Diagnostics, Mannheim, Germany) based on electrochemiluminescence immunoassay (ECLIA) technology. Results were reported in ng/mL, with a measurement range of 0.02–100 ng/mL. Analytical accuracy and reliability were maintained through internal quality-control procedures performed according to the manufacturer's instructions.

Patients' clinical progression was documented by the treating physicians and nursing staff and relevant clinical and laboratory information was obtained from the patients' medical records by trained data collectors. Microbiological Assessment: Bacteremia was defined as the isolation of a pathogenic bacterial species from one or more blood culture specimens. Blood cultures were obtained using sterile techniques before initiation of antibiotics whenever clinically feasible. Blood samples were collected from two separate venipuncture sites and processed in the hospital microbiology laboratory according to standard laboratory protocols, including incubation, organism identification, and antimicrobial susceptibility testing. Growth of a pathogenic organism in one or more blood culture specimens was considered diagnostic of bacteremia. Organisms considered likely contaminants when isolated from a single blood culture specimen included coagulase-negative staphylococci, *Bacillus* spp., *Propionibacterium acnes*, *Corynebacterium* spp., and *Micrococcus* spp., and were excluded from the analysis according to the predefined criteria.

Data was analyzed with the help of Statistical Package for the Social Sciences (SPSS) 26. Continuous variables were assessed for distribution and presented as median with interquartile range (IQR) because the procalcitonin levels and ICU stay were non-normally distributed. Categorical variables were presented as frequencies and percentages. Baseline demographic and clinical characteristics were summarized descriptively. The association between baseline procalcitonin categories and patient outcome (alive, dead and LAMA) was assessed using the Chi-square test or Fisher's exact test, as appropriate. Patients who left against medical advice were analyzed as a separate outcome category in descriptive and unadjusted analyses because their final hospital outcome could not be confirmed. Differences in baseline procalcitonin levels across the three patient outcome groups (alive, deceased, and LAMA) were assessed using the Kruskal–Wallis test. For comparison of procalcitonin levels between community-acquired and hospital-acquired bacteremia, the Mann–Whitney U test was used at baseline, day 5 and day 10. Available measurements for each time-point were used for serial PCT analyses and patients without follow-up PCT measurements were not used in the analysis for that time-point. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

A total of 199 patients who had bacteremia and were admitted to the intensive care unit were included in the final analysis. Demographic and clinical characteristics

are given in Table-I. Median age was 53.50 (40.80 - 68.90) years. Most participants were aged ≤ 60 years ($n=124$, 62.3%). A total of 118 (59.3%) participants were males. Median ICU stay was 11.70 (7.10 - 16.30) days. Regarding primary diagnosis, sepsis was the most common diagnosis ($n= 62$, 31.2%). Among comorbidities, diabetes mellitus was present in ($n=89$, 44.7%), Regarding the source of bacteremia, 116 (58.3%) had community-acquired bacteremia whereas 83 (41.7%) had hospital-acquired bacteremia. The overall median PCT level was 8.90 (5.10–13.70) ng/mL at baseline. Among patients with available follow-up measurements, median PCT levels were 5.70 (3.20–8.90) ng/mL on day 5 and 3.60 (2.00–5.60) ng/mL on day 10. At baseline, patients with hospital-acquired bacteremia had significantly higher median PCT levels than those with community-acquired bacteremia (10.20 vs. 8.10 ng/mL, $p=0.009$). Similarly, on day 5, median PCT was higher in hospital-acquired bacteremia (6.80 vs. 5.00 ng/mL, $p<0.001$) and this difference remained significant on day 10 (4.20 vs. 3.10 ng/mL, $p<0.001$) shown in Table-II. Among the 199 study participants, 128 patients were alive, 54 died, and 17 left against medical advice (LAMA). Overall, higher baseline PCT levels were observed among patients who died, compared with those who were alive or LAMA as p value < 0.001 shown in Table-III. Higher PCT categories were associated with poorer outcomes, particularly increased mortality, whereas lower PCT levels were associated with better survival as shown in Table-IV.

Table-I: Baseline demographic and clinical characteristics of study participants (n=199).

Variable	Category	Values
Age (years)	Median (IQR)	53.50 (40.80 - 68.90)
Age Group	≤ 60 years	124 (62.3%)
	> 60 years	75 (37.7%)
Gender	Male	118 (59.3)
	Female	81 (40.7)
ICU stay (days)	Median (IQR)	11.70 (7.10 - 16.30)
Primary diagnosis	Sepsis	62 (31.2%)
	Pneumonia	48 (24.1%)
	Urinary tract infection	31 (15.6%)
	Intra-abdominal infection	24 (12.1%)
	Others	34 (17.1%)
Diabetes mellitus	Yes	89 (44.7%)
Hypertension	Yes	76 (38.2%)
Chronic kidney disease	Yes	29 (14.6%)
Ischemic heart disease	Yes	25 (12.6%)
Community-acquired bacteremia	Yes	116 (58.3%)
Hospital-acquired bacteremia	Yes	83 (41.7%)

Table-II: Serial procalcitonin levels according to time and type of bacteremia.

Time point	Overall Median PCT (IQR) ng/mL	Community-acquired Median (IQR)	Hospital-acquired Median (IQR)	p-value
Baseline	8.90 (5.10–13.70)	8.10 (4.80–12.20)	10.20 (6.40–15.20)	0.009
Day 5	5.70 (3.20–8.90)	5.00 (2.80–7.60)	6.80 (4.10–10.20)	<0.001
Day 10	3.60 (2.00–5.60)	3.10 (1.80–4.80)	4.20 (2.40–6.50)	<0.001

Table-III. Baseline Procalcitonin Level According to Patient Outcome

Outcome	n	Baseline PCT Median (IQR), ng/mL	p-value
Alive	128	6.40 (3.80–9.50)	< 0.001
Dead	54	14.80 (10.90–19.30)	
LAMA	17	9.60 (5.90–13.80)	

Table-IV: Association of baseline procalcitonin categories with patient outcome.

Baseline PCT category (ng/mL)	Alive n (%)	Dead n (%)	LAMA n (%)	p-value
<5	58 (86.6)	5 (7.5)	4 (6.0)	<0.001
5–10	42 (68.9)	14 (23.0)	5 (8.2)	
>10	28 (39.4)	35 (49.3)	8 (11.3)	

DISCUSSION

Bacteremia continues to be a major cause of morbidity and mortality in the critically ill individual, especially one requiring intensive care. Due to the time interval that is often required for microbiological results to become available, early identification of patients at high risk of poor outcomes is difficult. The present study found a significant correlation between high pretreatment procalcitonin (PCT) levels and death in bacteremic patients in an intensive care unit (ICU). The concentrations of PCT at baseline were higher in patients who died than in survivors, indicating that greater inflammatory response may be linked to worse clinical outcomes.

Procalcitonin has been studied as a screening tool to evaluate the severity and prognosis of bacterial infections. The diagnostic and prognostic value of PCT in sepsis and critically ill patient cohorts have recently been appraised. The diagnostic value of serum PCT in adult sepsis was reported by Ghatak *et al.* and the performance of PCT and presepsin as biomarkers for the diagnosis of sepsis was reported by Chairaj *et al.*^{16,17} Likewise, Diab *et al.* showed that PCT in association with lactate clearance was useful for the prediction of mortality in sepsis and septic shock patients.¹⁸ These results suggest a correlation between elevated PCT levels and unfavourable outcome, as was found in the present study.

There was also evidence in the present study of significant decreases in serial PCT levels in those patients who had follow-up PCT levels performed. While falling PCT levels may indicate improved

systemic inflammation, this should still be interpreted in light of the clinical picture, microbiology results and the clinical response. PCT, inflammatory markers and clinical parameters have been assessed in patients with sepsis as a biomarker guided approach.^{19,20} Also, Yang *et al.* systematically reviewed and meta analyzed the diagnostic and prognostic value of PCT and high-sensitivity C-reactive protein in sepsis.²¹

PCT level was higher in hospital-acquired bacteremia and in the present study, it was an independent predictor of mortality. Hospital-acquired infections tend to be linked to more exposure to health care, invasive procedures, antimicrobial resistance and more clinical complexity. HABIs have been identified as significant infections in past studies and have been associated with adverse patient outcomes.²⁴ In addition, correct antimicrobial therapy and prompt start of therapy are important factors in the outcome of community-acquired bacteremia.²⁵

The positive association between a higher baseline PCT and mortality seen in this study is in line with previous data indicating that PCT might help identify patients who are more likely to have a worse prognosis. Effendi *et al.* showed the prognostic significance of PCT in the prediction of mortality in patients with Gram-negative sepsis and Biswas *et al.* gave an overview of the clinical use of PCT in the management of infection.^{22,23} The results of the current investigation, however, suggest a relationship and not an established predictive model.

LIMITATIONS

There are some limitations to this study. First, it took place in one tertiary-care hospital and involved adult

patients in ICUs only; thus, the results of the study might not apply to other hospitals or to patients with less severe infections. Second, the patient cohort was analyzed using multivariable logistic regression; however, potential for residual confounding (such as severity of illness, organ dysfunction, timing and appropriateness of antimicrobial therapy, pathogen characteristics, and source control measures) remains. Third, not all participants had serial PCT measurements. The reasons for missing follow-up measurements were primarily associated with discharge, death, or lack of samples. Therefore, attrition bias and survivor bias may have influenced the analysis of serial PCT trends as patients available at later time points may represent a clinically different subset. 17 patients who were discharged against medical advice were not included in the mortality modelling as the final outcome could not be confirmed. This exclusion could have created selection bias and should be taken into account when interpreting the mortality associations. The performance of the ROC/AUC, calibration, and external validation of the mortality prediction using PCT were not assessed. Hence, more prospective multi-center trials are needed to find out if PCT has added prognostic value beyond current clinical parameters.

CONCLUSION

The baseline PCT was associated with increased mortality and reduced clinical outcomes in bacteremic patients in ICU. In patients who had follow-up measurements available, serial decreases in PCT were seen, indicating a potential role for monitoring patients' disease process. PCT should be used as an additional biomarker and not as a lone prognostic tool.

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DISCLOSURES

None

CONFLICT OF INTEREST

None

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Declared none

AUTHOR CONTRIBUTION

Sidra Noor: Conceptualization, study design, data collection, manuscript drafting, final approval, accountable for all aspects of publication

Deedar Ali: Supervision, methodology, critical revision for intellectual content, final approval, final approval, accountable for all aspects of publication

Tooba Irfan: Data collection; data analysis; manuscript review; final approval, accountable for all aspects of publication

Ariba Afzal: Literature review; data interpretation; manuscript editing; final approval, accountable for all aspects of publication

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