Evaluation of the Diagnostic Value of Serum Procalcitonin, Lactate, and High-Sensitivity C-Reactive Protein for the Prediction of Bacteremia in Adult Patients in the Emergency Department

Supriya Pandey[1], Sushma BJ[1*], Bindu Rani[2]

[1]*Department of Biochemistry, National Institute of Medical Sciences & Research, NIMS University, Rajasthan, Jaipur, Pin- 303121*

[2]*Department of General Medicine, National Institute of Medical Science &Research, NIMS University, Rajasthan, Jaipur, Pin-303121*

***Correspondence:**

sushma2020@gmail.com

ABSTRACT

Early detection of bacteremia in adults presenting to the emergency department with suspected infection is essential for timely treatment. However, blood culture results are delayed, highlighting the need for rapid serum biomarkers. This study aimed to evaluate the diagnostic performance of procalcitonin (PCT), lactate, and high-sensitivity C-reactive protein (hs-CRP) for the early detection of bacteremia. This prospective observational study included adults aged over 18 years presenting to the emergency department with suspected infection. Blood cultures were obtained at presentation, along with simultaneous measurement of serum PCT, lactate, and hs-CRP levels. Bacteremia was defined as a positive blood culture after excluding contaminants. The diagnostic accuracy of each biomarker was assessed using receiver operating characteristic curve analysis. Patients with culture-confirmed bacteremia had significantly higher levels of PCT, lactate, and hs-CRP compared with culture-negative patients. PCT demonstrated the best diagnostic performance, with an area under the curve (AUC) of 0.71. At a cut-off value of 0.396, PCT showed 83.9% sensitivity and 43.8% specificity. Lactate and hs-CRP showed lower discriminatory ability, with AUC values of 0.59 and 0.60, respectively. Combining biomarkers improved diagnostic accuracy compared with individual markers. PCT was the most useful standalone biomarker for the early detection of bacteremia in emergency department adults with suspected infection. Lactate and hs-CRP had limited diagnostic performance when used alone but may provide complementary value when combined with PCT. These biomarkers may support early clinical decision-making, help guide antibiotic use, and reduce unnecessary antimicrobial exposure while awaiting blood culture results.

Keywords: Bacteremia, Emergency department, Procalcitonin, Lactate, hs-CRP, Biomarkers.

How to cite this article: Pandey S, Sushma BJ, Rani B. Evaluation of the Diagnostic Value of Serum Procalcitonin, Lactate, and High-Sensitivity C-Reactive Protein for the Prediction of Bacteremia in Adult Patients in the Emergency Department. Int J Drug Deliv Technol. 2026;16(68s):644-655. DOI: 10.25258/ijddt.16.68s.79

INTRODUCTION

Bacteremia the presence of viable bacteria in the bloodstream is a serious, potentially life-threatening condition frequently encountered in emergency departments (EDs). It often represents a pivotal stage of systemic infection and may rapidly progress to sepsis, septic shock, and multiple organ dysfunction when not recognized and treated early. Timely diagnosis remains difficult because many patients present with non-specific manifestations such as fever, tachycardia, hypotension, or altered mental status, which can also occur in non-infectious inflammatory states [1-3].

Blood culture is the reference standard for confirming bacteremia, yet it has important drawbacks. Results are delayed, sensitivity may be reduced in patients who have received antibiotics before sampling, and contamination can lead to misleading findings. Consequently, clinicians may initiate empirical broad-spectrum antibiotics while awaiting confirmation, a practice that can increase antimicrobial resistance, raise healthcare costs, and expose patients to avoidable adverse drug effects. These challenges underscore the need for rapid adjunctive tools that support early detection of bacteremia in emergency care [4,5].

In this context, serum biomarkers such as procalcitonin (PCT), lactate, and high-sensitivity C-reactive protein (hs-CRP) have been increasingly studied for early diagnosis and risk assessment in suspected bacterial infection. PCT is relatively more specific for bacterial etiologies, lactate reflects tissue hypoperfusion and illness severity, and hs-CRP indicates a systemic inflammatory response. Used individually or in combination, these markers may improve diagnostic discrimination and assist clinicians in making timely management decisions [6-11].

Accordingly, this study was conducted to determine the diagnostic value of serum PCT, lactate, and hs-CRP for predicting bacteremia among adults presenting to the ED with suspected infection. Specifically, we aimed to compare the sensitivity, specificity, and overall diagnostic accuracy of each biomarker alone and in combination using blood culture as the reference method and to clarify their

potential contribution to earlier diagnosis, more appropriate antibiotic selection, and improved clinical decision-making in emergency settings.

MATERIALS & METHODS

Study Design and Setting

The current research was an observational case-control study. This was a prospective observational study conducted on the subjects of sepsis patients who visited the Intensive Care Unit (ICU) at the General Medicine Department, National Institute of Medical Sciences (NIMS) College, Jaipur, Rajasthan.

Study Population

A total of 215 Adult patients (≥18 years) presenting to the emergency department with clinical suspicion of infection or sepsis and for whom blood cultures were indicated were enrolled after obtaining informed consent. Patients who had already received prolonged antibiotic therapy, had known chronic inflammatory conditions, malignancy, or incomplete laboratory data were excluded.

Data Collection

Baseline demographic data, clinical features, vital signs, and relevant laboratory parameters were recorded at admission. Clinical severity was assessed using standard sepsis-related clinical evaluation as per institutional protocol

Sample Collection and Laboratory Analysis

Blood samples were collected at the time of presentation, prior to initiation of antibiotics.

- Blood cultures were obtained under strict aseptic precautions and processed using standard microbiological techniques; culture positivity was considered the gold standard for diagnosing bacteremia.
- Serum procalcitonin (PCT) levels were measured using an immunoassay-based method.
- Serum lactate levels were estimated using an enzymatic method.
- High-sensitivity C-reactive protein (hs-CRP) was measured using a high-sensitivity immunoturbidimetric assay.

All investigations were performed in the central hospital laboratory following standard operating procedures

Outcome Measures

The primary outcome was the presence or absence of bacteremia confirmed by blood culture. The diagnostic performance of PCT, lactate, and hs-CRP-individually and in combination was evaluated against blood culture results.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics software. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, while categorical variables were expressed as frequencies and percentages. Diagnostic accuracy was assessed using receiver operating characteristic (ROC) curve analysis, and the area under the curve (AUC) with 95% confidence intervals was calculated. A p-value <0.05 was considered statistically significant

Ethical Considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants or their legally authorized representatives before enrolment.

RESULTS

Demographic Characteristics of the Study Population

A total of 215 individuals participated in this study, with the male participants being predominant (145 males, 67.4%) compared to female participants (70 females, 32.6%). This gender distribution, illustrated in Table 1 and Figure 1A, demonstrates a male-to-female ratio of approximately 2.1:1.

Table 1. Gender wise distribution of patients.

Gender	Frequency	Percentage
Male	145	67.44%
Female	70	32.56%
Total	215	100%

The age distribution presented in Table 2 revealed that the largest proportion of participants were in the 50 to 59 years age-group (48 patients, 22.3%), followed closely by the 40-49 years cohort (41 patients, 19.1%). Younger participants under 29 years represented the smallest group (20 patients, 9.3%).

Table 2. Age-wise distribution of study participants (N=215).

Age-group	Frequency	Percentage
≤ 29	20	9.30
30 - 39	37	17.21
40 - 49	41	19.07
50 - 59	48	22.33
60 - 69	37	17.21
≥ 70	32	14.88
Total	215	100.00

Age-gender-wise distribution has been listed in Table 3 and shown in Figure 1B. Among males, the majority of participants were observed in the 40-49 and 60-69 age groups (each 20.69%), followed closely by the 50–59 group (20%). Younger males

(≤29 years) comprised the smallest proportion (7.59%). In females, the 50-59 years age group had the highest representation (27.14%), with relatively even distribution across the 30-39 years (18.57%), 40-49 years (15.71%), and ≥70 years (15.71%) groups. The least number of female cases was in the 60-69 years age group (10%). Overall, middle-aged and older adults formed the bulk of the study population, with males showing a broader age spread and females peaking in the 50-59 years age-group.

Table 3. Age and gender distribution of study participants (N=215)

Age-group	Male, n (%)	Female, n (%)
≤ 29	11, (7.59%)	9, (12.86%)
30 - 39	24, (16.55%)	13, 18.57%)
40 - 49	30, (20.69%)	11, (15.71%)
50 - 59	29, (20.00%)	19, (27.14%)
60 - 69	30, (20.69%)	7, (10.00%)
≥ 70	21, (14.48%)	11, (15.71%)
Total	145, (100%)	70, (100%)

Blood Test Results of all Participants

The blood test reports for all participants, including haematological and biochemical parameters, are provided in Table 4. The average white blood cell count (TLC) was 13.5, but it varied a lot from as low as 1.5 to as high as 50. Most people had a count around 11.7, with half falling between 7.8 and 16.7. When checking the types of white cells, the mean percentage of neutrophils was 83%, with most people having between 77% to 93%. Monocytes averaged 3%, while mean lymphocytes were around 9.8%, but some had very low or high levels. For haemoglobin, the mean was 10.2, but it ranged widely from a very low 2.9 to a normal 17.5.

In the biochemistry reports, random blood sugar (RBS) mean was 143, but some had extremely high sugar (up to 1095 mg/dL) while others had very low (15.8). The usual range was between 88.5 to 148. Kidney function tests showed that creatinine mean was 3.3 mg/dL, but half the people had levels between 0.7 and 4.7, with some going up to 20.6. Urea was also high on average (94.5mg/dL), with most people between 37.6 to 122, but some had very high levels up to 513 mg.dL.

Overall, many participants had abnormal blood counts, high sugar, and signs of kidney problems, with some cases being very severe.

Table 4. Summary of hematological and biochemical parameters among all study participants

Variables	mean ± SD	median (IQR)	Range
Hematological parameters			
TLC (x1000/µL)	13.5 ± 7.8	11.7 (7.8 - 16.7)	1.5 - 50
Neutrophils (%)	83.0 ± 13.3	86.9 (77.4 - 92.9)	24.0 - 99.0
Monocytes (%)	3.0 ± 1.8	2.8 (1.8 - 4.0)	0.0 - 10.6
Lymphocytes (%)	9.8 ± 6.4	8.1 (5.0 - 14.4)	0.7 - 36.1
Hemoglobin (g/dL)	10.2 ± 2.9	10.3 (7.7 - 12.3)	2.9 - 17.5
Biochemical Parameters			
RBS (mg/dL)	143.3 ± 125	120.0 (88.5 - 148.0)	15.8 - 1095.0
Creatinine (mg/dL)	3.3 ± 3.7	1.6 (0.7 - 4.7)	0.4 - 20.6
Urea (mg/dL)	94.5 ± 84.8	72.0 (37.6 - 122.0)	0.4 - 513

Study of Procalcitonin as an inflammatory marker in all selected participants

The level of pro-calcitonin was recorded in all patients, and it was noted that most of the patients (104, 48.4%) had >2.00 ng/ml procalcitonin, followed by 75 cases (34.9%) having 0.05-0.5 ng/ml procalcitonin concentration, and 34 patients (15.8%) having 0.51-2.00 ng/ml concentration. Only 2 cases (0.9%) had less than 0.05 ng/ml procalcitonin (Table 5, Figure 1C).

Table 5. Procalcitonin level wise distribution of study participants.

Procalcitonin (In ng/ml)	n = 215	In %
< 0.05	2	0.93%
0.05 - 0.500	75	34.88%
0.51 - 2.00	34	15.81%
> 2.00	104	48.37%

Study of HS-CRP concentration as an inflammatory marker in all participants

Table 6 and Figure 1D show the hs-CRP concentration in the studied patients. The data represented that amongst 215 cases, 150 participants (69.8%) had >3.0 mg/dL of hs-CRP, 41 cases (19.1%) had 1.3-3.0 mg/dL concentration and 24 cases (11.2%) had <1.0 mg/dL hs-CRP level.

Table 6. HS-CRP level wise distribution of study participants.

HS-CRP (In mg/dL)	n = 215	In %
< 1.0	24	11.16%
1.0 - 3.0	41	19.07%
> 3.0	150	69.77%

Study of lactate as an inflammatory marker in all participants

The level of lactate was recorded in all patients and it was noted that 185 individuals (86%) had >19.8 mg/dL lactate, followed by 30 cases (13.9%) having 4.5-19.8 mg/dL concentration. None of the

participants had <4.5 mg/dL lactate concentration (Table 7, Figure 1E).

Table 7. Lactate level wise distribution of study participants

Lactate (In mg/dL)	n = 215	In %
< 4.5	0	0.00%
4.5 - 19.8	30	13.95%
> 19.8	185	86.05%

Table 8 summarizes the average concentration, median and range of all the studied inflammatory markers, namely- procalcitonin, hs-CRP and lactate among all the studied cases. It was noted that procalcitonin ranged within 0.03-468.8 ng/ml in all cases. The average 13.85 ng/ml procalcitonin (SD 37.7 ng/ml) with a median IQR of 1.68 (0.37-15.5) was recorded in participants.

Table 8. Descriptive statistics of procalcitonin, HS-CRP and lactate

Variables	Range	Median (IQR)	Mean ± SD
Procalcitonin (ng/ml)	0.03 - 468.8	1.68 (0.366-15.5)	13.85 ± 37.70
HSCRP (mg/dL)	0.358 - 84.8	6.17 (2.02-29.42)	15.07 ± 18.08
Lactate (mg/dL)	18.45 - 138.78	25.11 (21.24-37.08)	37.38 ± 27.82

The hs-CRP ranged within 0.358-84.8 mg/dL in all cases. The average 15.07 mg/dL hs-CRP (SD 18.08 mg/dL) with a median IQR of 1.68 (0.37-15.5) mg/dL was recorded in participants.

The concentration of lactate ranged within 18.45 - 138.78 mg/dL in all participants. The average 37.38 mg/dL lactate (SD 27.8 mg/dL) with a median IQR of 25.11 (21.24-37.08) mg/dL was recorded in participants.

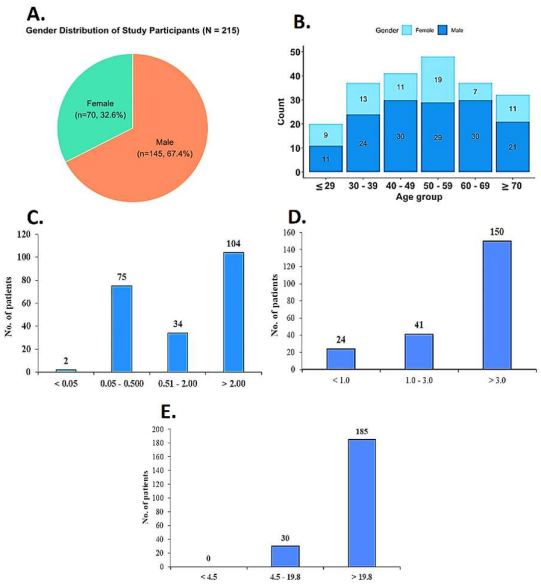

Figure 1. (A) Gender distribution of study participants, displaying absolute counts (n) and relative percentages (%) **(B)** Stacked bar plot showing age and gender distribution of study participants (N=215). **(C)** Graph of procalcitonin distribution of study participants. **(D)** Bar plot of HS-CRP distribution of study participants. **(E)** Bar plot of lactate distribution of study participants.

Bacterial Growth and Distribution Analysis

Out of the total samples analysed, 52.1% (n = 112) exhibited bacterial growth, while 47.9% (n = 103) showed no growth (Figure 2, top left, Table 9). Among the culture-positive samples, Gram-negative bacteria were predominant, accounting for 71.4% (n = 80), whereas Gram-positive bacteria comprised only 28.6% (n = 32) of the isolates (Figure 2, top right).

A further breakdown of the Gram-positive bacteria (Figure 2, middle) revealed that the most commonly isolated genus was *Staphylococcus* (N = 18, 56%), followed by *Micrococcus* (N = 7, 22%), *Enterococcus* (N = 4, 13%) and *Bacillus* (N = 3, 9%). *Staphylococcus* represented the largest portion, indicating its significant role in Gram-positive infections in this cohort.

Among the Gram-negative isolates (Figure 2, bottom), *Pseudomonas* was the most frequently identified genus, comprising 31 (39%) isolates, followed by *Escherichia* (n = 22, 28%), *Acinetobacter* (n = 12, 15%), *Klebsiella* and *Enterobacter* (n = 7, 9% each), and *Sphingomonas* (n = 1, 1%). The dominance of *Pseudomonas* indicates a high prevalence of opportunistic and potentially drug-resistant pathogens within the Gram-negative category.

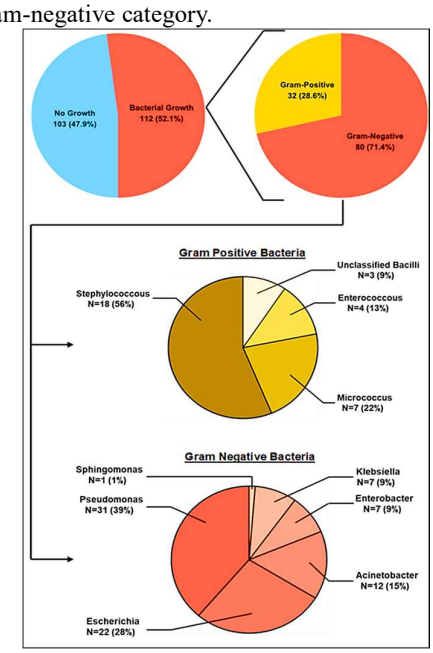

Figure 2: Distribution of bacterial growth.

Top left: Pie chart showing the proportion of samples with bacterial growth (52.1%) and those with no growth (47.9%); **Top right:** Among culture-positive samples, Gram-negative bacteria were more prevalent (71.4%) than Gram-positive bacteria (28.6%); **Middle:** Distribution of Gram-positive bacterial genera; **Bottom:** Distribution of Gram-negative bacterial genera; Percentages and isolate counts are indicated alongside each genus.

Table 9. Bacterial growth obtained

Microbial growth	Frequency	Percentage
No colonies	103	47.91%
Bacterial colonies	112	52.09%
Total	215	100%

Table 10, Figure 3 shows a detailed breakdown of the bacterial isolates. Among the Gram-negative bacteria (n = 80), the most frequently isolated species identified was *Escherichia coli* (n = 22, 27.5%), followed by *Pseudomonas aeruginosa* (n = 13, 16.3%). Other isolates included *Pseudomonas spp.* (n = 18, 22.5%) and *Acinetobacter spp.* (n = 10), *Enterobacter cloacae* (n = 5), *Klebsiella pneumoniae* (n = 4), *Klebsiella spp.* (n = 3), *Enterobacter aerogenes* (n = 2), *Acinetobacter baumannii* (n = 2), and *Sphingomonas* (n = 1). Among the Gram-positive bacteria (n = 32), *Staphylococcus aureus* accounted for nearly half the isolates (n = 15, 46.9%), highlighting its clinical importance. Other Gram-positive isolates included *Micrococcus* (n = 7), *Enterococcus* (n = 4), *Staphylococcus spp.* (n = 3), and *Bacillus* spp. (n = 3).

Table 10. Identified bacterial isolates from culture-positive samples

Gram-staining	Bacteria	Count	Percentage
Gram Negative (n=80)	*Acinetobacter baumannii*	2	2.5%
	Acinetobacter spp.	10	12.5%
	Enterobacter aerogenes	2	2.5%
	Enterobacter cloacae	5	6.25%
	Escherichia coli	22	27.5%
	Klebsiella Pnemonia	4	5%
	Klebsiella spp.	3	3.75%
	Pseudomonas spp	18	22.5%
	Pseudomonas aerogenosa	13	16.25%
	Sphinogomonas	1	1.25%
Gram Positive (n=32)	*Bacilli*	3	9.38%
	Enterococcous	4	12.5%
	Micrococcus	7	21.88%
	Staphylcoccus aureus	15	46.88%
	Staphylococcous	3	9.38%

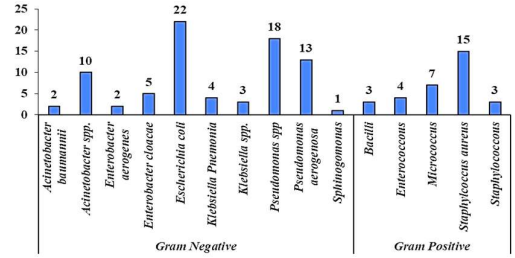

Figure 3. Bar plot of bacterial isolates from culture-positive samples.

Demographic Characteristics by Bacterial Growth Status

The mean age was comparable between the two groups (53.1 ± 15.9 vs. 50.3 ± 16.1 years, p = 0.22), with similar median ages (53.5 [IQR: 40.5-66.0] vs. 50.0 [IQR: 38.5-63.0]). Age distribution was wide in both groups (range: 19-88 vs. 23-86 years). Gender distribution did not differ significantly (p = 1.0), with males comprising 67.9% (n = 76) of the bacterial growth group and 67.0% (n = 69) of the no-growth group. The results are presented in Table 11.

The age distribution of participants was assessed across both groups (Table 12, Figure 4). In the bacterial growth group, the majority of individuals were aged between 50-59 years (21.4%) and 60-69 years (21.4%), followed closely by those aged 30-39 years (17.9%) and 40-49 years (17.0%). In the no growth group, the largest proportion was observed in the 50-59 age group (23.3%), followed by 40-49 years (21.4%) and 30-39 years (16.5%). Participants aged ≥70 years comprised 15.2% in the bacterial growth group and 14.6% in the no growth group, while the youngest age group (≤29 years) accounted for 7.1% and 11.7%, respectively.

Table 11. Comparison of age and gender characteristics between patients with and without bacterial growth.

Variable	Bacterial Growth	No Growth	p-Value
Age (years)			
Mean ± SD	53.1 ± 15.9	50.3 ± 16.1	0.22
Median (IQR)	53.5 (40.5 – 66.0)	50.0 (38.5 – 63.0)	
Range	19 – 88	23 – 86	
Gender, n (%)			
Male	76 (67.9%)	69 (67.0%)	0.99
Female	36 (32.1%)	34 (33.0%)	

Data presented as mean ± standard deviation, median (interquartile range), or frequency (percentage); p-values from independent Mann-Whitney U test (age) and chi-square test (gender); ≤0.05 p-value=significant

Table 12. Age-wise distribution of patients with and without bacterial growth in blood culture

Age (Years)	Bacterial Growth		No Growth		p-value
	Frequency (%)	%	Frequency	%	
≤29	8	7.1	12	11.7	0.51
30 - 39	20	17.9	17	16.5	
40 - 49	19	17	22	21.4	
50 - 59	24	21.4	24	23.3	
60 - 69	24	21.4	13	12.6	
≥70	17	15.2	15	14.6	

Data presented as frequency (percentage); p-value calculated using chi-square tes; ≤0.05 p-value=significant

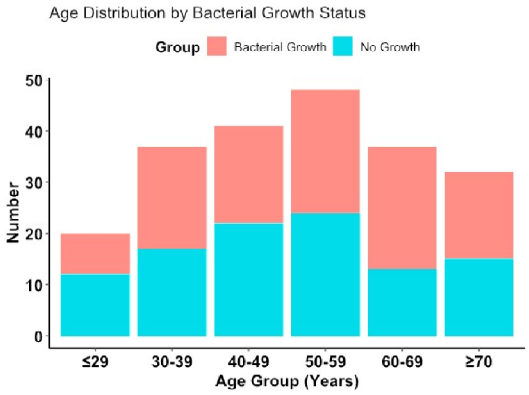

Figure 4. Age-wise distribution of patients with and without bacterial growth in blood culture.

Hematological Profile Comparison Between Bacterial Growth and No Growth Groups

Hematological parameters including total leukocyte count (TLC), neutrophil percentage, monocyte percentage, lymphocyte percentage, and haemoglobin levels were compared between the bacterial growth and no growth groups. Table 13 shows the comparative analysis of these parameters between the two group.

The TLC was significantly elevated in the bacterial growth group compared to the no growth group ($p = 0.02$). Notably, neutrophil percentages were substantially higher in the bacterial growth group than in the no growth group ($p < 0.001$), consistent with a neutrophilic response in bacterial infections (Table 13).

Table 13. Comparison of hematological parameters between patients with and without bacterial growth in blood cultures.

Variables	Bacterial Growth			No Growth			p-value
	Mean± SD	Median (IQR)	Range	Mean± SD	Median (IQR)	Range	
TLC	15.1 ± 9.1	12.6 (8.6 - 19.8)	4.3 - 50.0	11.7 ± 5.6	11.3 (7.0 - 15.2)	1.5 - 24.7	0.02
Neutrophils	86.1 ± 11.7	89.8 (80.6 - 94.1)	24.0 - 98.5	79.7 ± 14.3	85.2 (70.7 - 91.0)	41.0 - 97.8	<0.001
Monocytes	3.0 ± 1.9	2.8 (1.70 - 4.0)	0.0 - 10.6	3.0 ± 1.6	2.9 (1.8 - 4.1)	0.0 - 8.9	0.71
Lymphocytes	9.3 ± 6.6	7.3 (4.2 - 13.6)	0.7 - 36.1	10.4 ± 6.0	9.2 (5.3 - 15.0)	1.0 - 30.3	0.08
Hemoglobin	10.0 ± 3.0	9.7 (7.6 - 12.1)	3.9 - 17.5	10.5 ± 2.8	10.6 (8.4 - 12.4)	2.9 - 17.5	0.2

Comparison of Biochemical Parameters Between Groups

Biochemical parameters, including random blood sugar (RBS), creatinine, and urea levels, were compared between the bacterial growth and no growth groups (Table 14). Although higher mean RBS (162.9 ± 164.2 mg/dL vs. 121.9 ± 50.3 mg/dL), creatinine (3.3 ± 4.1 mg/dL vs. 3.3 ± 3.3 mg/dL), and urea (94.9 ± 91.8 mg/dL vs. 94.1 ± 76.3 mg/dL) levels were observed in the bacterial growth group, these differences were not statistically significant ($p = 0.38$, 0.46, and 0.58, respectively).

Table 14. Comparison of Biochemical parameters between patients with and without bacterial growth in blood cultures

Variables	Bacterial Growth			No Growth			p-value
	Mean ± SD	Median (IQR)	Range	Mean ± SD	Median (IQR)	Range	

RBS (mg/dL)	162.9 ± 164.2	124.3 (83.8 - 156.3)	15.8 - 1095.0	121.9 ± 50.3	116.0 (90.0 - 138.0)	45.9 - 297.0	0.38
Creatinine (mg/dL)	3.3 ± 4.1	1.5 (0.7 - 4.0)	0.4 - 20.6	3.3 ± 3.3	1.8 (0.7 - 5.0)	0.4 - 20.3	0.46
Urea (mg/dL)	94.9 ± 91.8	61.3 (38.0 - 115.8)	0.4 - 513.0	94.1 ± 76.3	76.0 (32.0 - 122.0)	10 - 435	0.58

Association of Hematological and Biochemical Parameters with Bacterial Growth

To further examine the association between clinical parameters and the presence of bacterial infection, a multiple logistic regression analysis was performed using the glm function with binomial family, adjusted for age and gender (Figure 5A). The analysis revealed that a higher total leukocyte count (TLC) was significantly associated with bacterial growth (OR: 2.04, 95% CI: 1.11-3.86, p=0.021), as was an elevated neutrophil percentage (OR: 2.14, 95% CI: 1.13-4.19, p=0.022). Conversely, monocyte and lymphocyte percentages, as well as hemoglobin levels, did not show significant associations (p>0.05). Among biochemical parameters, random blood sugar (RBS) levels were significantly higher in patients with bacterial growth (OR: 2.5, 95% CI: 1.31-5.06, p=0.006), suggesting a possible link between hyperglycemia and infection. However, creatinine and urea levels were not significantly associated with bacterial presence. These findings underscore the potential of routine hematological and biochemical markers particularly TLC, neutrophils, and RBS in indicating bacterial infections.

Inflammatory Markers in Relation to Bacterial Growth

Further comparisons between patients with and without bacterial growth were made for inflammatory parameters (Table 15). Serum procalcitonin levels were markedly elevated in individuals with bacterial growth, with a median (IQR) of 2.4 (0.5-18.1) ng/mL compared to 0.4 (0.2-2.6) ng/mL in those without bacterial growth (p<0.001). Similarly, high-sensitivity C-reactive protein (hsCRP) levels were significantly higher among infected individuals (median 9.6 (5.0-16.7 mg/L) than those without infection (median 6.7 (3.0-12.2) mg/L, p=0.01). Lactate levels were also significantly elevated in the bacterial growth group (median: 28.1 (22.4-54.7) mg/dL) compared to the no-growth group (median: 24.4 (21.2-35.3) mg/dL, p=0.03). These findings suggest that inflammatory markers like procalcitonin and hsCRP, as well as urea, may serve as valuable indicators for differentiating bacterial infections in clinical settings.

Table 15. Comparison of Inflammatory markers between patients with and without bacterial growth in blood cultures.

Variables	Bacterial Growth			No Growth			p-value
	Mean ± SD	Median (IQR)	Range	Mean ± SD	Median (IQR)	Range	
Pro-calcitonin	17.8 ± 48.3	2.4 (0.5 - 18.1)	0.1 - 468.8	4.8 ± 12.6	0.4 (0.2 - 2.6)	0.01 - 86.9	< 0.001
hs-CRP	13.6 ± 12.0	9.6 (5.0 – 16.7)	1.0 – 57.0	11.0 ± 11.9	6.7 (3.0 – 12.2)	1.5 – 55.0	0.01
Lactate	41.3 ± 29.3	28.1 (22.4 – 54.7)	18.46 – 140.8	34.8 ± 24.5	24.4 (21.2 – 35.3)	18.5 – 135.8	0.03

Predictive Value of Inflammatory and Metabolic Markers

In the multivariable logistic regression model adjusted for age and gender, elevated procalcitonin levels were strongly associated with the presence of bacterial growth, with an odds ratio (OR) of 5.1 (95% CI: 2.55-11.18, p<0.001). Similarly, hsCRP showed a significant independent association with bacterial infection, with an OR of 3.8 (95% CI: 1.92-7.90, p<0.001). Lactate levels also emerged as a significant predictor, with an OR of 2.1 (95% CI: 1.08-4.11, p=0.03). These findings indicate that procalcitonin, hsCRP, and lactate are independently associated with bacterial infection and may serve as reliable biomarkers in diagnostic evaluation (Figure 5B).

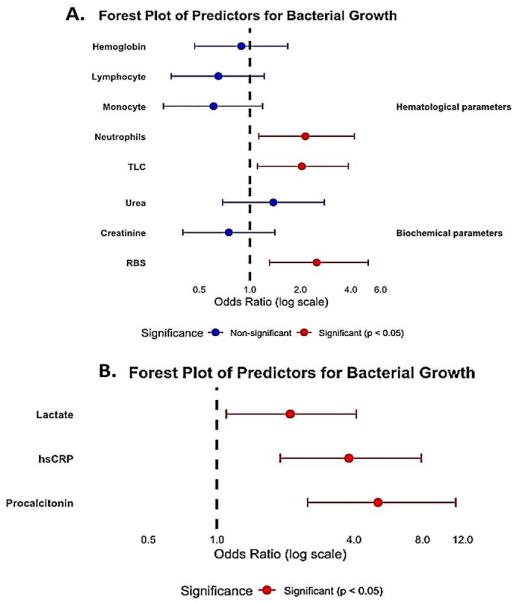

Figure 5. **(A)** Forest plot of hematological and biochemical predictors for bacterial growth in blood cultures. **(B)** Forest plot of inflammatory predictors for bacterial growth in blood cultures

Receiver Operating Characteristic (ROC) Curve Analysis

To further evaluate the diagnostic performance of the three biomarkers Procalcitonin, high-sensitivity C-reactive protein (HSCRP), and Lactate in distinguishing blood culture-positive from blood culture-negative patients, ROC curve analysis was performed.

As illustrated in Figure 6, the ROC curve for Procalcitonin showed the highest discriminative ability with an Area Under the Curve (AUC) of 0.71, followed by hs-CRP with an AUC of 0.60, and Lactate with a relatively lower AUC of 0.59. These findings indicate that Procalcitonin has superior sensitivity and specificity characteristics compared to the other two markers in the context of bacteremia detection.

The ROC curves also visually highlight this performance, with the Procalcitonin curve lying farthest from the diagonal line (line of no discrimination), indicating better predictive accuracy. HSCRP showed moderate performance, while Lactate demonstrated the least utility in this diagnostic setting.

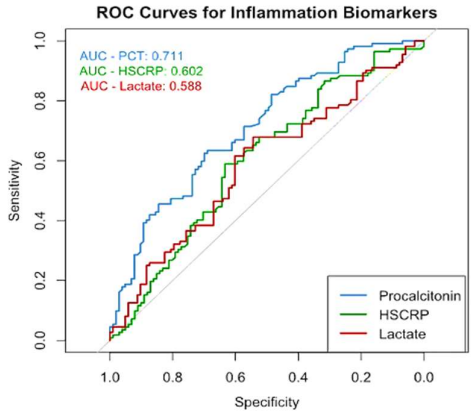

Figure 6. Receiver operating characteristic (ROC) curves for inflammation biomarkers in predicting bacterial growth.

Table 16, sums-up the area under the curve, sensitivity and specificity of all the markers studied in the present study. Procalcitonin showed highest sensitivity (83.9%) and 43.8% specificity; hs-CRP had 74.1% sensitivity; and 42% specificity and lactate had 69.4% sensitivity and 38.45% specificity.

Table 16. Diagnostic accuracy in prediction of bacterial growth

Variables	AUC	95% Confidence Interval	Cut-off Value	Sensitivity	Specificity
Procalcitonin	0.711	0.674 - 0.82	0.396	83.90%	43.80%
HS-CRP	0.602	0.543 - 0.698	2.745	74.10%	42%
Lactate	0.588	0.515 - 0.67	52.2	69.40%	38.45%

DISCUSSION

Bacteremia, defined as the presence of bacteria in the bloodstream, can progress to sepsis, a severe and potentially fatal syndrome characterized by a dysregulated host immune response to infection. This systemic dysregulation leads to widespread organ dysfunction and is associated with substantial global morbidity and mortality [12-14]. Bacteremia contributes significantly to global deaths annually, as invasive bacteria proliferate in the blood and trigger a rapid, dysregulated systemic inflammatory cascade [15]. However, the current diagnostic gold standard for bacteremia blood culture has several limitations, including a long turnaround time (5-7 days), risk of contamination, and false-negative

results. These drawbacks may delay timely treatment and adversely affect patient outcomes [16].

This study evaluated the diagnostic value of inflammatory biomarkers, including procalcitonin (PCT), high-sensitivity C-reactive protein (hsCRP), and lactate, by comparing patients with confirmed bacterial growth to those without bacterial infection. In addition to inflammatory markers, hematological and biochemical parameters were compared between the two groups. Our results provide key insights into the diagnostic and prognostic utility of these parameters for distinguishing bacterial infections from non-infectious conditions.

Bacterial growth was detected in 52.1% of samples, with Gram-negative bacteria (71.4%) predominating over Gram-positive species (28.6%). This finding is consistent with reports of an increasing burden of Gram-negative pathogens in healthcare settings (17). The most frequent Gram-negative isolates were Pseudomonas spp. (39%), Escherichia coli (27.5%), and Acinetobacter spp. (15%), which are well recognized as causes of hospital-acquired and opportunistic infections [17]. Among Gram-positive organisms, Staphylococcus aureus (46.9%) was the most common, reflecting its persistent role in both community- and healthcare-associated infections [18].

The rising burden of Gram-negative bloodstream infections (BSIs) is a major public health concern. In 2019, BSIs were associated with an estimated 2.91 million deaths globally, with Gram-negative pathogens implicated in more than half of these cases [19]. Alongside changing epidemiology, the distribution of causative pathogens and their antimicrobial resistance profiles have also evolved substantially [20].

Surveillance data indicate a steady increase in Gram-negative BSIs over time. For example, the SENTRY surveillance program reported an increase from 33.5% in 1997 to 43.4% in 2016, with *E. coli* overtaking *S. aureus* as the leading causative agent [21]. Similar trends have been reported regionally; in China, the proportion of Gram-negative BSIs increased from 58.4% in 2014 to 73.0% by 2019 [22]. This shift is further complicated by escalating antibiotic resistance, particularly to carbapenems [23].

Haematologically, patients with bacteremia demonstrated higher total leukocyte count (TLC), and neutrophil percentage was significantly associated with bacterial growth. This is consistent with the established view that leukocytosis and neutrophilia are common features of bacterial infection [24]. Although leukocytosis is frequently used as an indicator of microbial infection, its predictive value for bacteremia has been inconsistent across studies, and threshold values remain non-standardized [25-30]. Furthermore, hematological disorders, non-infectious inflammatory diseases, trauma, and surgery can confound interpretation[31]. The markedly higher neutrophil percentage observed in the bacterial growth group supports neutrophilic predominance as a hallmark of acute bacterial infection and suggests that neutrophil percentage may be more discriminatory than TLC alone [32-33].

In contrast, lymphocyte and monocyte percentages did not differ significantly between groups, suggesting limited discriminatory value in this setting. While monocytes contribute to phagocytosis and antigen presentation, their peripheral proportion may not rise as sharply as neutrophils in acute bacterial infection [34]. Haemoglobin levels also did not differ significantly, which may reflect heterogeneity in underlying conditions in the study population, despite reports linking anaemia to chronic infection [35-36].

Among biochemical parameters, creatinine and urea showed no significant differences between groups. Random blood sugar (RBS) was higher in the bacterial growth group, and regression analysis demonstrated a significant association with bacterial growth, consistent with evidence that hyperglycemia can impair immune function and increase infection risk [37]. Dysglycemia is common in severe infections, though patterns may vary by illness severity and timing, with early stress responses often producing hyperglycemia via increased hepatic gluconeogenesis and glycogenolysis, while hypoglycemia may occur in more severe states when glucose consumption exceeds synthesis [38-45]. As our cohort included patients with bacteremia rather than sepsis, the observed hyperglycemia may reflect an early stress response.

Among inflammatory biomarkers, PCT was the strongest predictor of bacterial infection, consistent with its established role in bacterial infections and sepsis [46]. PCT showed superior discriminative performance (AUC: 0.71) compared with hsCRP (AUC: 0.60) and lactate (AUC: 0.59), aligning with evidence supporting its diagnostic utility [47-49]. Although hsCRP was elevated in the bacterial growth group, its lower specificity limits its use as a standalone marker. Lactate was significantly higher in infected patients ($p = 0.03$) but demonstrated the lowest AUC, indicating limited diagnostic discrimination in this cohort, though it remains useful for risk stratification in emergency and critical care settings [50].

Biologically, PCT is a precursor of the hormone calcitonin, and its levels rise during systemic inflammatory responses particularly bacterial infections due to increased production by multiple tissues [51]. Similarly, CRP is an acute-phase reactant that increases rapidly in response to inflammation from infection or tissue injury.

Importantly, PCT, hsCRP, and lactate can be measured in less than one hour, offering a practical advantage over blood culture and enabling earlier antibiotic decision-making. While PCT appears to be the most reliable single biomarker, a multiparametric approach incorporating hsCRP, lactate, neutrophilia, hyperglycemia, and clinical assessment may improve diagnostic accuracy and shorten the time to appropriate therapy when bacteremia is strongly suspected.

CONCLUSION

This study demonstrates that integrating inflammatory biomarkers with routine hematological and biochemical tests can improve the early identification of bacteremia. Gram-negative pathogens were predominant most notably *Pseudomonas* spp. and *Escherichia coli* while Staphylococcus aureus continued to represent a clinically significant Gram-positive cause. Patients with bacteremia showed significantly higher total white blood cell (WBC) counts, marked neutrophilia, and elevated random blood sugar, whereas other blood indices and renal function markers contributed less to discrimination. Among the evaluated biomarkers, procalcitonin showed the best diagnostic performance, exceeding the accuracy of C-reactive protein (CRP) and lactate, which were helpful but less specific. Given the inherent delays and diagnostic constraints of blood culture, rapid assays such as procalcitonin used alongside standard laboratory findings may support earlier diagnosis and more appropriate antibiotic initiation. This combined strategy is particularly important amid escalating antimicrobial resistance and has the potential to enhance clinical outcomes.

Abbreviations

PCT: Procalcitonin; **CRP:** C-reactive protein **hs-CRP:** High-sensitivity C-reactive protein; **Eds**: Emergency departments; **ICU**: Intensive Care Unit; **NIMS**: National Institute of Medical Sciences; **ROC**: Receiver operating characteristic; **AUC:** Area under the curve; **RBS:** Random blood sugar; **TLC:** Total leukocyte count; **WBC:** White blood cell.

Ethical Approval

This study involved patient samples from NIMS Hospital. Ethical approval was obtained from the Institutional Ethics Committee (Approval No. 134427) for this study.

Acknowledgement

NA

Conflict of Interest

The authors declare that they have no conflicts of interest.

Funding Statement

NA

Reference

1. Smith, D. A., and S. M. Nehring. "Bacteremia." StatPearls. Treasure Island (FL): StatPearls Publishing (2023).
2. Costa, S. P., and C. M. Carvalho. "Burden of bacterial bloodstream infections and recent advances for diagnosis." Pathogens and Disease 80, no. 1 (2022): ftac027.
3. Sweeney, T. E., O. Liesenfeld, and L. May. "Diagnosis of bacterial sepsis: why are tests for bacteremia not sufficient?" Expert Review of Molecular Diagnostics 19, no. 11 (2019): 959-962.
4. Martinez, R. M., and D. M. Wolk. "Bloodstream infections." In Diagnostic Microbiology of the Immunocompromised Host (2016): 653-689.
5. Chela, H. K., A. Vasudevan, C. Rojas-Moreno, and S. H. Naqvi. "Approach to positive blood cultures in the hospitalized patient: a review." Missouri Medicine 116, no. 4 (2019): 313.
6. He, R.-R., G.-L. Yue, M.-L. Dong, J.-Q. Wang, and C. Cheng. "Sepsis biomarkers: advancements and clinical applications: a narrative review." International Journal of Molecular Sciences 25, no. 16 (2024): 9010.
7. Lin, C.-T., J.-J. Lu, Y.-C. Chen, V. C. Kok, and J.-T. Horng. "Diagnostic value of serum procalcitonin, lactate, and high-sensitivity C-reactive protein for predicting bacteremia in adult patients in the emergency department." PeerJ 5 (2017): e4094.
8. Zhang, H., J. Zhao, Z. Wang, M. Huang, Z. Tan, J. Jiang, et al. "Unveiling promising sepsis biomarkers: a clinical perspective." All Life 17, no. 1 (2024): 2369569.
9. Lee, S. M., and W. S. An. "New clinical criteria for septic shock: serum lactate level as new emerging vital sign." Journal of Thoracic Disease 8, no. 7 (2016): 1388.
10. Jagannatha, S. B. Study of Serum High Sensitivity C-Reactive Protein, Ferritin, Insulin, C-Peptide and Glycated Hemoglobin in Patients with Type 2 Diabetes Mellitus. Rajiv Gandhi University of Health Sciences (India), 2014.
11. Jagannatha, S. B., and S. Chandrakar. "Study of Serum High-Sensitivity C-Reactive Protein, Ferritin and Glycated Hemoglobin Levels in Patients with Type 2 Diabetes Mellitus." International Journal of Science and Research 50 (2016): 50.
12. Jirak, P., F. Haertel, M. Mirna, R. Rezar, M. Lichtenauer, V. Paar, et al. "A comparative analysis of novel biomarkers

in sepsis and cardiovascular disease." Applied Sciences 12, no. 3 (2022): 1419.
13. Font, M. D., B. Thyagarajan, and A. K. Khanna. "Sepsis and septic shock basics of diagnosis, pathophysiology and clinical decision making." Medical Clinics 104, no. 4 (2020): 573-585.
14. Xu, X., Y. Wang, Y. Tao, W. Dang, B. Yang, and Y. Li. "The role of platelets in sepsis: a review." Biomolecules and Biomedicine 24, no. 4 (2024): 741.
15. Fernando, S. M., B. Rochwerg, and A. J. Seely. "Clinical implications of the third international consensus definitions for sepsis and septic shock (Sepsis-3)." CMAJ 190, no. 36 (2018): E1058-E1059.
16. Bonnet, E., L. Maulin, E. Senneville, B. Castan, C. Fourcade, P. Loubet, et al. "Clinical practice recommendations for infectious disease management of diabetic foot infection (DFI): 2023 SPILF." Infectious Diseases Now 54, no. 1 (2024): 104832.
17. Peleg, A. Y., H. Seifert, and D. L. Paterson. "Acinetobacter baumannii: emergence of a successful pathogen." Clinical Microbiology Reviews 21, no. 3 (2008): 538-582.
18. Tong, S. Y., J. S. Davis, E. Eichenberger, T. L. Holland, and V. G. Fowler Jr. "Staphylococcus aureus infections: epidemiology, pathophysiology, clinical manifestations, and management." Clinical Microbiology Reviews 28, no. 3 (2015): 603-661.
19. Zha, L., S. Li, J. Guo, Y. Hu, L. Pan, H. Wang, et al. "Global and regional burden of bloodstream infections caused by carbapenem-resistant Gram-negative bacteria in 2019: a systematic analysis from the MICROBE database." International Journal of Infectious Diseases 153 (2025): 107769.
20. Kern, W., and S. Rieg. "Burden of bacterial bloodstream infection: a brief update on epidemiology and significance of multidrug-resistant pathogens." Clinical Microbiology and Infection 26, no. 2 (2020): 151-157.
21. Diekema, D. J., P.-R. Hsueh, R. E. Mendes, M. A. Pfaller, K. V. Rolston, H. S. Sader, et al. "The microbiology of bloodstream infection: 20-year trends from the SENTRY antimicrobial surveillance program." Antimicrobial Agents and Chemotherapy 63, no. 7 (2019): e00355-19.
22. Tabah, A., N. Buetti, Q. Staiquly, S. Ruckly, M. Akova, A. T. Aslan, et al. "Epidemiology and outcomes of hospital-acquired bloodstream infections in intensive care unit patients: the EUROBACT-2 international cohort study." Intensive Care Medicine 49, no. 2 (2023): 178-190.
23. Kinross, P., C. Gagliotti, H. Merk, D. Plachouras, D. L. Monnet, L. D. Högberg, et al. "Large increase in bloodstream infections with carbapenem-resistant Acinetobacter species during the first 2 years of the COVID-19 pandemic, EU/EEA, 2020 and 2021." Eurosurveillance 27, no. 46 (2022): 2200845.
24. Walling, H. W., and F. A. Manian. "Predictive value of leukocytosis and neutrophilia for bloodstream infection." Infectious Diseases in Clinical Practice 12, no. 1 (2004): 2-6.
25. Bates, D. W., E. F. Cook, L. Goldman, and T. H. Lee. "Predicting bacteremia in hospitalized patients: a prospectively validated model." Annals of Internal Medicine 113, no. 7 (1990): 495-500.
26. Leibovici, L., S. Greenshtain, O. Cohen, F. Mor, and A. J. Wysenbeek. "Bacteremia in febrile patients: a clinical model for diagnosis." Archives of Internal Medicine 151 (1991): 1801-1806.
27. Mellors, J., J. Kelly, R. Gusberg, S. Horwitz, and R. Horwitz. "A simple index to estimate the likelihood of bacterial infection in patients developing fever after abdominal surgery." The American Surgeon 54 (1988): 558-564.
28. Bota, D. P., C. Mélot, F. L. Ferreira, and J.-L. Vincent. "Infection Probability Score (IPS): a method to help assess the probability of infection in critically ill patients." Critical Care Medicine 31 (2003): 2579-2584.
29. Müller, B., S. Harbarth, D. Stolz, R. Bingisser, C. Mueller, J. Leuppi, et al. "Diagnostic and prognostic accuracy of clinical and laboratory parameters in community-acquired pneumonia." BMC Infectious Diseases 7 (2007): 10.
30. Bossink, A. W., A. J. Groeneveld, and L. G. Thijs. "Prediction of microbial infection and mortality in medical patients with fever: plasma procalcitonin, neutrophilic elastase-α1-antitrypsin, and lactoferrin compared with clinical variables." Clinical Infectious Diseases 29 (1999): 398-407.
31. Wu, Y., G. Wang, Z. Huang, B. Yang, T. Yang, J. Liu, et al. "Diagnostic and therapeutic value of biomarkers in

urosepsis." Therapeutic Advances in Urology 15 (2023): 17562872231151852.
32. Sahoo, B., B. Thakur, M. K. Jain, and R. Mishra. "C-reactive protein as a diagnostic marker of bacterial infection in febrile children." Journal of Clinical and Diagnostic Research 12 (2018): SC05-SC08.
33. Kolaczkowska, E., and P. Kubes. "Neutrophil recruitment and function in health and inflammation." Nature Reviews Immunology 13 (2013): 159-175.
34. Auffray, C., M. H. Sieweke, and F. Geissmann. "Blood monocytes: development, heterogeneity, and relationship with dendritic cells." Annual Review of Immunology 27 (2009): 669-692.
35. Barrett-Connor, E. "Anemia and infection." The American Journal of Medicine 52 (1972): 242–253.
36. Were, T., G. Davenport, J. Hittner, C. Ouma, J. Vulule, J. Ong'Echa, et al. "Bacteremia in Kenyan children presenting with malaria." Journal of Clinical Microbiology 49 (2011): 671-676.
37. Atamna, A., G. Ayada, A. Akirov, T. Shochat, J. Bishara, and A. Elis. "High blood glucose variability is associated with bacteremia and mortality in patients hospitalized with acute infection." QJM: An International Journal of Medicine 112 (2019): 101-106.
38. Mizock, B. A. "Alterations in carbohydrate metabolism during stress: a review of the literature." The American Journal of Medicine 98 (1995): 75-84.
39. Miller, S. I., R. J. Wallace Jr, D. M. Musher, E. J. Septimus, S. Kohl, and R. E. Baughn. "Hypoglycemia as a manifestation of sepsis." The American Journal of Medicine 68 (1980): 649-654.
40. Shilo, S., S. Berezovsky, Y. Friedlander, and M. Sonnenblick. "Hypoglycemia in hospitalized nondiabetic older patients." Journal of the American Geriatrics Society 46 (1998): 978-982.
41. Alamgir, S., N. B. Volkova, and M. W. Peterson. "Prognostic value of low blood glucose at the presentation of E. coli bacteremia." The American Journal of Medicine 119 (2006): 952-957.
42. Lang, C. H., G. J. Bagby, and J. J. Spitzer. "Glucose kinetics and body temperature after lethal and nonlethal doses of endotoxin." American Journal of Physiology Regulatory, Integrative and Comparative Physiology 248 (1985): R471-R478.
43. Cherrington, A., H. Fuchs, R. Stevenson, P. Williams, K. Alberti, and K. Steiner. "Effect of epinephrine on glycogenolysis and gluconeogenesis in conscious overnight-fasted dogs." American Journal of Physiology Endocrinology and Metabolism 247 (1984): E137-E144.
44. Wolfe, R. R., D. Elahi, and J. J. Spitzer. "Glucose kinetics in dogs following a lethal dose of endotoxin." Metabolism 26 (1977): 847-850.
45. Lang, C. H., Z. Spolarics, A. Ottlakan, and J. J. Spitzer. "Effect of high-dose endotoxin on glucose production and utilization." Metabolism 42 (1993): 1351-1358.
46. Sahu, S., and G. Dutta. "Emerging evidence for serum procalcitonin estimation at point-of-care and advancement in quantitative sensing strategies over the past decade." Sensors International 2 (2021): 100107.
47. Wacker, C., A. Prkno, F. M. Brunkhorst, and P. Schlattmann. "Procalcitonin as a diagnostic marker for sepsis: a systematic review and meta-analysis." The Lancet Infectious Diseases 13 (2013): 426-435.
48. Kibe, S., K. Adams, and G. Barlow. "Diagnostic and prognostic biomarkers of sepsis in critical care." Journal of Antimicrobial Chemotherapy 66 (2011): ii33-ii40.
49. Kim, M. H., G. Lim, S. Y. Kang, W.-I. Lee, J.-T. Suh, and H. J. Lee. "Utility of procalcitonin as an early diagnostic marker of bacteremia in patients with acute fever." Yonsei Medical Journal 52 (2011): 276.
50. Freund, Y., S. Delerme, H. Goulet, M. Bernard, B. Riou, and P. Hausfater. "Serum lactate and procalcitonin measurements in emergency room for the diagnosis and risk-stratification of patients with suspected infection." Biomarkers 17 (2012): 590-596.
51. Linscheid, P., D. Seboek, E. S. Nylen, I. Langer, M. Schlatter, K. L. Becker, et al. "In vitro and in vivo calcitonin I gene expression in parenchymal cells: a novel product of human adipose tissue." Endocrinology 144 (2003): 5578-5584.