Utility of Procalcitonin in Antibiotic Stewardship for Sepsis: Findings from a Prospective Observational Study

Mariyah Yousuf, Dalip K Kakru Deepak Sharma

Abstract

Background

Inappropriate and prolonged use of antibiotics contributes significantly to antimicrobial resistance, increased healthcare costs, and adverse drug events. Procalcitonin (PCT), a biomarker that rises in bacterial infections and declines with resolution, has emerged as a valuable tool to guide antibiotic therapy.

Objectives:

To evaluate the role of procalcitonin levels in guiding antibiotic initiation, escalation, and de-escalation in hospitalized patients with suspected bacterial infections.

Materials and Methods:

This prospective observational study was conducted at a Sharda hospital, a tertiary care teaching hospital under the School of Medical Sciences & Research (SMS&R), over a defined study period. A total of 97 patients with complete demographic, clinical, laboratory, and treatment data were included in the final analysis. Procalcitonin levels were measured at admission, 24 hours, and 72 hours. Antibiotic usage patterns, escalation or de-escalation decisions, vital parameters, blood culture results, and clinical outcomes were recorded and analyzed.

Results:

The mean age of the study population was 46.2 ± 15.8 years, with a male predominance (59.8%). Procalcitonin levels showed a declining trend in 66.0% of patients. Antibiotic de-escalation was achieved in 50.5%, while escalation was required in 28.9% of cases. Blood culture positivity was observed in 35.1% of patients and was associated with higher admission procalcitonin levels. Clinical improvement was documented in 73.2% of patients.

Conclusion

Procalcitonin-guided antibiotic therapy facilitates rational antimicrobial use, promotes timely de-escalation, and is associated with favorable clinical outcomes. Incorporation of procalcitonin into antibiotic stewardship programs may reduce unnecessary antibiotic exposure in hospitalized patients.

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Introduction

Antimicrobial resistance (AMR) has emerged as one of the most critical global health challenges, threatening the effective prevention and treatment of infectious diseases worldwide. The World Health Organization has identified AMR as a major public health crisis driven primarily by inappropriate, excessive, and prolonged use of antibiotics[1]. Hospitalized patients, particularly those with suspected bacterial infections, are frequently exposed to empirical broad-spectrum antimicrobial therapy due to diagnostic uncertainty[2].

Early differentiation between bacterial infections and non-bacterial inflammatory conditions remains challenging in routine clinical practice[3]. Conventional laboratory markers such as total leukocyte count, erythrocyte sedimentation rate, and C-reactive protein are widely used but lack sufficient specificity to reliably distinguish bacterial infections[4]. Moreover, these markers may remain elevated even after clinical resolution, leading to unnecessary continuation of antibiotics[5]. Blood culture remains the gold standard for microbiological diagnosis; however, it has several inherent limitations including delayed results, low sensitivity, prior antibiotic exposure, and contamination[6]. As a result, clinicians often continue empirical antibiotics for extended durations, contributing to antimicrobial resistance, drug toxicity, and increased healthcare costs[7]. Procalcitonin (PCT), a 116-amino-acid precursor of the hormone calcitonin, has gained significant attention as

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Keywords

Procalcitonin, Antibiotic stewardship, Bacterial infection, Biomarker, De-escalation

a biomarker for bacterial infections[8]. Under physiological conditions, procalcitonin is produced in minimal quantities by thyroid C-cells. During systemic bacterial infections, procalcitonin production is markedly upregulated in multiple extrathyroidal tissues under the influence of bacterial endotoxins and pro-inflammatory cytokines[9]. In contrast, viral infections suppress procalcitonin synthesis via interferon-gamma, conferring relative specificity to bacterial infections[10].

Numerous studies have demonstrated that procalcitonin levels correlate with the severity of bacterial infection and decrease with effective antimicrobial therapy[11,12]. This dynamic kinetic profile makes procalcitonin a valuable biomarker not only for diagnosis but also for monitoring treatment response and guiding antibiotic duration[13].

Procalcitonin-guided antibiotic stewardship algorithms have been evaluated extensively in conditions such as sepsis, lower respiratory tract infections, and intensive care unit (ICU) settings[14-16]. Randomized controlled trials have shown that procalcitonin-based protocols significantly reduce antibiotic exposure without increasing mortality or treatment failure[17-18].

Despite growing evidence from high-income countries, data from resource-limited settings and heterogeneous hospitalized populations remain limited[19]. Differences in patient profiles, prevalence of co-morbidities, microbial spectrum, and antibiotic practices necessitate evaluation of procalcitonin-guided therapy in local clinical settings[20].

Furthermore, real-world adherence to biomarker-guided algorithms may vary, and clinicians often integrate biomarker values with clinical judgment rather than relying solely on predefined cut-offs[21]. Therefore, observational studies reflecting routine clinical practice are essential to understand the practical utility of procalcitonin in guiding antibiotic therapy[22].

The present study was undertaken to evaluate the role of serial procalcitonin measurements in guiding antibiotic initiation, escalation, and de-escalation in hospitalized patients with suspected bacterial infections and to assess its association with microbiological findings and clinical outcomes[23-28].

Materials and methods

This was a Prospective observational study carried out in the department of Microbiology, at a Tertiary care teaching hospital, conducted over a defined study period (12 months). Hospitalized patients with suspected bacterial infection in whom procalcitonin testing was performed as part of routine clinical care. A total of 97 patients with complete demographic, clinical, laboratory, and treatment data were included in the final analysis.

Data Collection

Data were collected using a structured proforma including:

- Demographic details
- Co-morbidities
- Procalcitonin levels at admission, 24 hours, and 72 hours
- Antibiotic therapy at admission, 24 hours, and 72 hours
- Escalation or de-escalation decisions
- Vital parameters
- Blood culture results
- Clinical outcomes

Laboratory Methods

Procalcitonin levels were measured using standardized immunoassay techniques as per hospital laboratory protocol. Blood cultures were processed using automated culture systems following standard microbiological guidelines.

Inclusion Criteria

1. Hospitalized patients with suspected bacterial infection
2. Procalcitonin measured at admission
3. Documented antibiotic therapy
4. Availability of follow-up procalcitonin and treatment decision data

Exclusion Criteria

1. Incomplete clinical or laboratory data
2. Patients with proven viral infections without bacterial co-infection
3. Patients discharged or expired before follow-up evaluation

Outcome Measures

- Trend of procalcitonin levels
- Antibiotic escalation or de-escalation
- Blood culture positivity
- Clinical outcome (improvement, no improvement, deterioration)

Statistical Analysis

Data were entered into Microsoft Excel and analyzed descriptively. Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequency and percentage.

Results

A total of 97 patients with complete clinical, laboratory, and treatment-related data were included in the final analysis. The mean age of the study population was 46.2 ± 15.8 years, with patients ranging from young adults to elderly individuals, indicating a wide age distribution. Males constituted a higher proportion of the study population (59.8%) compared to females (40.2%). A significant proportion of patients (62.9%) had one or more underlying co-morbid conditions, while 37.1% had no documented co-morbidities.

Table 1. Baseline Demographic Characteristics of Study Population (n = 97)

Variable	Value
Mean age (years) ± SD	46.2 ± 15.8
Age range (years)	18–82
Sex (Male)	58 (59.8%)
Sex (Female)	39 (40.2%)
Patients with ≥1 co-morbidity	61 (62.9%)
Patients without co-morbidities	36 (37.1%)

Table 2. Distribution of Co-morbidities among Patients (n = 97)

Co-morbidity	Number (%)
Diabetes mellitus	29 (29.9%)
Hypertension	34 (35.1%)
Diabetes + Hypertension	17 (17.5%)
Chronic kidney disease	9 (9.3%)
Chronic lung disease	6 (6.2%)
No co-morbidities	36 (37.1%)

Table 3. Procalcitonin Levels at Different Time Intervals (ng/dL)

Time of Measurement	Mean ± SD	Median (IQR)
At admission	6.8 ± 4.9	5.9 (3.1–8.6)
At 24 hours	4.3 ± 3.6	3.7 (2.0–5.4)
At 72 hours	2.1 ± 2.4	1.5 (0.7–2.9)

Table 4. Trend of Procalcitonin Levels Over Time (n = 97)

Procalcitonin trend	Number (%)
Decreasing trend	64 (66.0%)
Persistently elevated	21 (21.6%)
Increasing trend	12 (12.4%)

Table 5. Antibiotics Used at Different Time Points

TIME INTERVAL	BROAD-SPECTRUM ANTIBIOTICS N (%)	NARROW-SPECTRUM ANTIBIOTICS N (%)
AT ADMISSION	73 (75.3%)	24 (24.7%)
AT 24 HOURS	59 (60.8%)	38 (39.2%)
AT 72 HOURS	41 (42.3%)	56 (57.7%)

Table 6. Antibiotic Stewardship Decision Based on Procalcitonin Levels

Treatment decision	Number (%)
Antibiotics escalated	28 (28.9%)
Antibiotics de-escalated	49 (50.5%)
No change	20 (20.6%)

Table 7. Vital Parameters of Study Population (n = 97)

Parameter	Mean ± SD
Heart rate (beats/min)	96.4 ± 14.2
Temperature (°C)	38.1 ± 0.9

Table 8. Blood Culture Results of Study Population

Blood culture result	Number (%)
Positive	34 (35.1%)
Negative	63 (64.9%)

Graph1: Procalcitonin levels

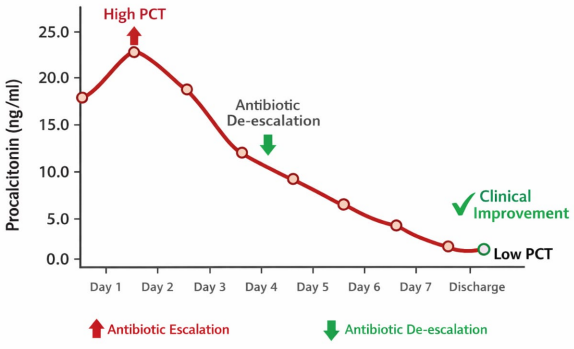


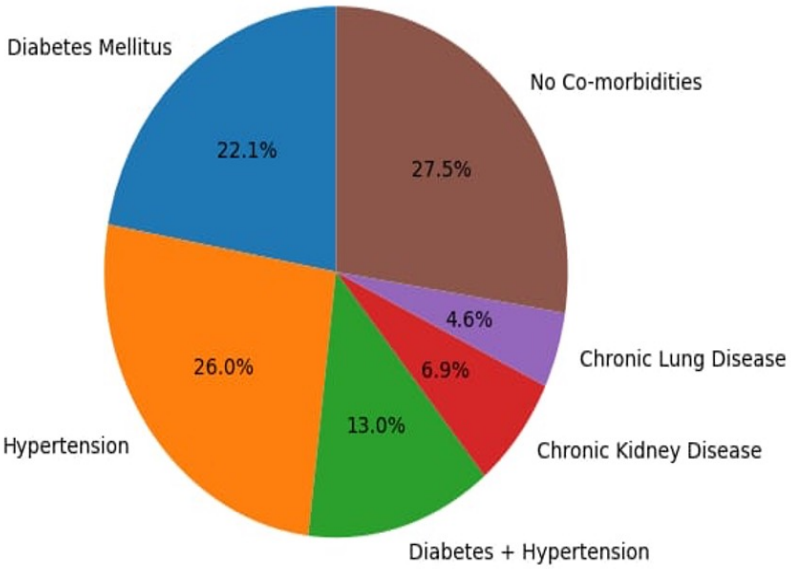
Table 9. Association of Blood Culture Positivity with Procalcitonin Levels

Blood culture	Mean Procalcitonin at admission (ng/dL)
Positive	9.2 ± 5.1
Negative	5.1 ± 3.8

Table 10. Summary of Clinical Outcomes Based on Procalcitonin-Guided Therapy

Outcome	Number (%)
Clinical improvement	71 (73.2%)
No significant improvement	18 (18.6%)
Clinical deterioration	8 (8.2%)

Graph 2:Distribution of C0-morbidities among participants (n=97)



Procalcitonin levels showed a **progressive decline over time** in the majority of patients. The **mean procalcitonin level at admission** was **6.8 ± 4.9 ng/dL**, which decreased to **4.3 ± 3.6 ng/dL at 24 hours** and further declined to **2.1 ± 2.4 ng/dL at 72 hours**. A **decreasing procalcitonin trend** was observed in **66.0%** of patients, indicating favorable response to therapy. However, **21.6%** of patients showed persistently elevated levels, while **12.4%** demonstrated an increasing trend, suggestive of ongoing or worsening infection.

Antibiotic usage patterns changed over time in accordance with procalcitonin trends. At admission, the majority of patients (**75.3%**) were initiated on **broad-spectrum antibiotics**. By 24 hours, a gradual shift toward narrower-spectrum therapy was observed. At 72 hours, **57.7%** of patients were receiving **narrow-spectrum antibiotics**, reflecting effective antibiotic de-escalation guided by clinical and biomarker response.

Based on procalcitonin levels and clinical assessment, **antibiotic de-escalation** was achieved in **50.5%** of patients, while **28.9%** required escalation of therapy. No change in antibiotic regimen was observed in **20.6%** of cases. These findings demonstrate the practical utility of procalcitonin-guided antibiotic stewardship in optimizing antimicrobial use.

Analysis of vital parameters showed a **mean heart rate of 96.4 ± 14.2 beats per minute** and a **mean body temperature of 38.1 ± 0.9°C**, consistent with systemic inflammatory response in the study population. Blood culture positivity was detected in **35.1%** of patients, while **64.9%** had negative culture results. Patients with positive blood cultures had **significantly higher mean procalcitonin levels at admission** compared to culture-negative patients, supporting the role of procalcitonin as a marker of bacterial infection.

Regarding clinical outcomes, **73.2%** of patients showed clear clinical improvement during hospital stay. A smaller proportion (**18.6%**) showed no significant improvement, while **8.2%** experienced clinical deterioration. Favorable outcomes were more commonly observed in patients with declining procalcitonin levels and successful antibiotic de-escalation.

Discussion

The present study assessed the utility of procalcitonin as a biomarker for guiding antibiotic therapy in hospitalized patients with suspected bacterial infections. Serial procalcitonin measurements were used to evaluate trends in infection severity, antibiotic escalation or de-escalation decisions, and clinical outcomes. The findings support the growing evidence that procalcitonin-guided management contributes to rational antibiotic use and favorable patient outcomes.

The study population consisted predominantly of middle-aged adults with a male predominance, consistent with previous studies conducted in hospital and ICU settings[28,29]. A high proportion of patients

had associated co-morbidities such as diabetes mellitus and hypertension, which are well-known risk factors for infection severity and adverse outcomes[30]. The presence of these co-morbidities underscores the importance of precise antimicrobial decision-making in this population[31].

Elevated procalcitonin levels at admission were observed in the majority of patients, reflecting underlying bacterial infection or systemic inflammatory response. Several studies have demonstrated that admission procalcitonin levels correlate with bacterial load and disease severity[32,33]. The findings of the present study are in agreement with previous literature, supporting the diagnostic value of procalcitonin in suspected bacterial infections[34].

Serial measurement of procalcitonin revealed a declining trend in most patients, indicating effective infection control and response to antimicrobial therapy. The importance of procalcitonin kinetics rather than isolated values has been emphasized in multiple studies, as declining levels are associated with favorable outcomes[35,36]. Persistently elevated or rising procalcitonin levels, as observed in a subset of patients, may indicate ongoing infection, treatment failure, or complications[37].

Antibiotic de-escalation was achieved in more than half of the study population. This finding is consistent with randomized trials and meta-analyses demonstrating that procalcitonin-guided strategies significantly reduce antibiotic duration and exposure[17,38]. Reduced antibiotic use has been associated with lower risk of antimicrobial resistance, drug-related adverse events, and healthcare costs[39]. Approximately one-third of patients required escalation of antibiotic therapy due to persistently elevated or increasing procalcitonin levels. This highlights the role of procalcitonin not only in reducing antibiotic use but also in identifying patients who may benefit from intensified therapy or further diagnostic evaluation[40,41].

Blood culture positivity was observed in around one-third of patients, which is comparable to rates reported in previous hospital-based studies[42]. Higher admission procalcitonin levels among culture-positive patients further reinforce the specificity of procalcitonin for bacterial infections[43]. However, culture-negative patients with elevated procalcitonin levels may represent partially treated infections or fastidious organisms[44].

The majority of patients demonstrated clinical improvement, particularly those with declining procalcitonin levels and successful antibiotic de-escalation. Several studies have reported similar associations between decreasing procalcitonin levels and improved survival and recovery[45,46]. Conversely, persistently elevated procalcitonin has been linked to poor prognosis and higher mortality[47].

The findings of the present study are consistent with international and Indian studies that have demonstrated the safety and efficacy of procalcitonin-guided antibiotic therapy across diverse clinical settings[14,18,20]. Differences in de-escalation rates and culture positivity may be attributed to variations in patient populations and local microbiological patterns[48].

Incorporation of procalcitonin into routine clinical practice can assist clinicians in making evidence-based decisions regarding antibiotic use. When combined with clinical judgment, procalcitonin serves as a valuable adjunct in antibiotic stewardship programs aimed at curbing antimicrobial resistance[49,50].

Conclusion

Procalcitonin-guided antibiotic therapy is a valuable tool in optimizing antimicrobial use among hospitalized patients with suspected bacterial infections. Serial procalcitonin measurements assist clinicians in making informed decisions regarding antibiotic escalation and de-escalation, thereby reducing unnecessary antibiotic exposure while maintaining favorable clinical outcomes. Integration of procalcitonin into antibiotic stewardship programs can play a significant role in combating antimicrobial resistance.

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