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Original Research Article

Pro-calcitonin as a marker of sepsis in a NICU setup in comparison to C-reactive protein

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ABSTRACT

Background: Neonatal sepsis is a major cause of morbidity and mortality, particularly in developing countries. Early diagnosis is difficult because clinical signs are non-specific, blood culture requires 48–72 hours and may have limited sensitivity, while C-reactive protein (CRP) rises relatively late. Procalcitonin (PCT) increases earlier during bacterial infection and may serve as a useful diagnostic marker. This study evaluated PCT as an early marker of neonatal sepsis and compared its diagnostic performance with CRP.

Methods: This prospective cross-sectional study was conducted in the NICU of Al Ameen Medical College, Bijapur, Karnataka, from May 2024 to April 2025. Seventy-five neonates aged less than 72 hours with clinical features or risk factors for sepsis were enrolled. Investigations included complete blood count, absolute neutrophil count, immature-to-total neutrophil ratio, CRP, PCT and blood culture. CRP≥10 mg/l and PCT>0.5 ng/ml were considered positive. Neonates were classified as proven sepsis, suspected sepsis or no sepsis. Data were analysed using Chi-square and Fisher's exact tests.

Results: Of 75 neonates, 46 (61.3%) were male and 39 (52.0%) had low birth weight. Blood culture was positive in 7 cases (9.3%), with *Staphylococcus aureus* being the most common isolate. PCT showed higher sensitivity than CRP (85.7% vs 42.8%) and a higher negative predictive value (97.5% vs 93.4%), whereas CRP had greater specificity (83.8% vs 58.8%).

Conclusions: PCT is a more sensitive early marker than CRP for neonatal sepsis. Its high negative predictive value makes it useful for ruling out sepsis and guiding antibiotic decisions.

Keywords: C-reactive protein, Early onset sepsis, NICU, Negative predictive value, Neonatal sepsis, Procalcitonin, Sensitivity

INTRODUCTION

Neonatal sepsis remains one of the most challenging clinical problems in neonatal intensive care units worldwide. It is responsible for approximately 1.6 million neonatal deaths annually in developing countries, with an incidence in India of 30 per 1000 live births and a contribution of 19% to all neonatal deaths.[1,2] Despite advances in neonatal care, early and accurate diagnosis remains elusive because the clinical signs of neonatal sepsis such as respiratory distress, lethargy, temperature instability and feed intolerance are non-specific and indistinguishable from many non-infectious conditions. This diagnostic ambiguity leads to either under-treatment, with potentially fatal consequences or over-treatment with broad-spectrum antibiotics, contributing to increased costs, adverse drug effects and the emergence of antimicrobial resistance.[3] Laboratory evaluation of the neonate suspected of sepsis conventionally includes complete blood count, absolute neutrophil count (ANC) and the immature-to-total neutrophil ratio (I:T ratio).

These haematological indices, while widely available, lack adequate sensitivity, particularly in the early phase of infection when clinical intervention is most critical.[3] Blood culture, the definitive diagnostic standard, requires a minimum of 48–72 hours and its sensitivity is further compromised by the small volumes of blood obtainable from neonates, prior antibiotic exposure and the transient nature of bacteraemia. Sensitivity for blood culture in detecting neonatal sepsis has been reported as low as 30–50% in some series.[4]

C-reactive protein (CRP) has been used for decades as an acute-phase reactant in the diagnosis of neonatal sepsis. Synthesised by the liver in response to cytokine stimulation, CRP begins to rise 6–8 hours after the onset of infection and peaks at 24–48 hours.[5] Its sensitivity at the time of initial presentation is only approximately 60%, improving to 82–84% with serial measurements at 24 and 48 hours.[6] This lag severely limits its utility for early-onset sepsis diagnosed within the first 72 hours of life. CRP has thus been characterised as a 'specific but late' marker of neonatal infection and a single measurement is considered insufficient to guide antibiotic decisions at the time of admission.[5,6]

PCT the precursor of calcitonin, is produced by monocytes and parenchymal cells including those of the liver, lung, kidney and muscle in response to bacterial endotoxins and pro-inflammatory cytokines such as tumour necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6).[7] Its kinetics are markedly superior for early diagnosis: the latent period is approximately 4 hours, with peak levels at 6–12 hours and a plasma elimination half-life of 20–30 hours.[6] In healthy individuals, serum PCT is below 0.05 ng/ml, while in patients with systemic sepsis, levels may rise to 1000 ng/ml. Concentrations above 10 ng/mL are almost exclusively associated with severe sepsis or septic shock.[7] Unlike CRP, PCT concentrations remain low or undetectable in viral infections, localised bacterial infections, allergic disorders and autoimmune diseases, conferring a degree of specificity for systemic bacterial infection. PCT also demonstrates utility in differentiating sepsis from the non-infectious systemic inflammatory response syndrome (SIRS) and in monitoring the response to antibiotic therapy, as levels return to baseline rapidly when infection resolves.[8]

Despite these advantages, data on PCT as a diagnostic marker in neonatal sepsis from Indian NICU settings remain scarce. Most published studies have focused on Western and European populations, where the microbiological profile differs substantially from that seen in developing countries. In India, gram-negative organisms, particularly *Klebsiella*, *E. coli* and Pseudomonas, predominate in neonatal sepsis, unlike the gram-positive GBS-dominant pattern in developed countries.[4] This study was therefore undertaken to evaluate the role of PCT as an early marker of neonatal sepsis in a tertiary care NICU in Hyderabad and to compare its diagnostic performance with CRP, with a view to establishing whether PCT should be incorporated into the routine neonatal sepsis screen.

METHODS

Study design and setting

This was a hospital-based prospective cross-sectional study conducted in the Neonatal Intensive Care Unit (NICU) of Al Ameen Medical College, Bijapur, Karnataka, over a period of 12 months from May 2024 to April 2025. Ethical approval was obtained from the Institutional Ethics Committee. Written and informed consent was obtained from the parents or guardians of all enrolled neonates prior to enrolment.

Study population and sample size

All neonates admitted to the NICU within the study period who were aged less than 72 hours and had clinical features or risk factors suggestive of sepsis were considered for enrolment. Sample size was calculated using the formula: $n=Z^2\times$sensitivity $(1-$sensitivity$)/$precision^2, using a reported PCT sensitivity of 57%,6 an alpha of 0.05 and power of 80%, yielding a minimum of 67 subjects. Seventy-five neonates were enrolled to account for potential dropout or incomplete data.

Inclusion and exclusion criteria

Neonates were eligible for inclusion if they were aged less than 72 hours, had clinical features or maternal risk factors suggestive of sepsis, had a gestational age greater than 28 weeks and had a birth weight greater than 1000 g. Neonates were excluded if they had a gestational age of less than 28 weeks, a birth weight of less than 1000 g, were already receiving antibiotic therapy at the time of enrolment, were aged more than 72 hours or had known congenital anomalies.

Clinical criteria for sepsis

The clinical criteria taken as indicative of sepsis encompassed three domains. Maternal risk factors included fever within two weeks prior to delivery, prolonged rupture of membranes (>12 hours), meconium-stained or foul-smelling liquor, more than three vaginal examinations during labour, prolonged labour (sum of first and second stage >24 hours) and maternal urinary tract infection within two weeks of delivery. Neonatal risk factors included low birth weight (1000–2500 g), premature birth (28–37 weeks) and perinatal asphyxia (Apgar score <4 at one minute). Signs and symptoms of sepsis included refusal to feed, feeding intolerance, lethargy, excessive irritability, high-pitched cry, seizures, temperature instability, apnoea, respiratory distress, poor perfusion, tachycardia, bradycardia, abdominal distension, necrotising enterocolitis, vomiting and

sclerema. Gestational age was assessed using the modified Ballard scoring system.

Sample collection and processing

Approximately 5 ml of blood was collected from a peripheral venous site under aseptic conditions. From this, 1 mL was inoculated into a paediatric Bact Alert PF blood culture bottle; 2 ml was collected into a sterile plain bottle for serum separation for PCT and CRP estimation; and 2 ml was collected in an EDTA-containing tube for haematological analysis. All samples were obtained before initiation of antibiotic therapy.

Blood culture

Blood culture was performed using the Bact/Alert 3D automated microbial detection system (bioMérieux). The system monitors carbon dioxide production using a colorimetric sensor: when microbial growth produces CO_2, the sensor in the culture bottle changes colour from blue-green to yellow, triggering an audible alarm. Positive cultures underwent Gram staining, followed by subculture on sheep blood agar and MacConkey agar, incubated for 14–18 hours. Organism identification and antibiotic susceptibility testing were performed using the bioMérieux ATB system.

C-reactive protein estimation

CRP was measured using the immunoturbidometry method on the COBAS C 311 automated analyser (Roche). The principle involves latex microparticles coated with anti-CRP mouse monoclonal antibodies reacting with CRP in the sample to form an antigen-antibody complex. The complex is quantified turbidimetrically. The minimum detectable concentration is 1 mg/l. A CRP value of ≥10 mg/l was defined as abnormal and indicative of infection.

Procalcitonin estimation

PCT was measured using an immunoluminometric assay on the COBAS E 411 automated analyser (ELECSYS BRAHMS PCT, Roche, Germany). The assay employs a sandwich principle with two incubation steps: first, the antigen in the sample reacts with a biotinylated monoclonal PCT-specific antibody and a ruthenium-complex-labelled monoclonal PCT-specific antibody to form a sandwich complex; second, addition of streptavidin-coated microparticles binds the complex to the solid phase via biotin-streptavidin interaction.

Chemiluminescent emission is induced by voltage application, measured by a photomultiplier and results are determined via a calibration curve. The measuring range was 0.02–100 ng/ml. Interpretation was as follows: PCT <0.5 ng/ml indicated no sepsis; 0.5–2.0 ng/ml indicated probable sepsis with significant but moderate systemic inflammatory response; and >2.0 ng/ml indicated sepsis or severe systemic inflammatory response most likely due to bacterial infection.

Haematological parameters

Total leukocyte count (TLC), absolute neutrophil count (ANC) and band cell ratio (I:T ratio) were determined from EDTA blood. Leishman-stained thin blood films were prepared for manual differential counts. Abnormal values were defined as: TLC<5000/mm³, ANC <1800/mm³ and I:T ratio >20%, as per the criteria of Manroe et al and Lloyd et al.[9,10]

Classification of neonates

Based on blood culture results and clinical findings, neonates were classified into three groups. Group A (proven sepsis) comprised neonates with a positive blood culture and clinical symptoms of sepsis. Group B (suspected sepsis) comprised neonates with a negative blood culture but who had either two or more signs of sepsis with at least one abnormal laboratory parameter or one or more signs with two or more abnormal laboratory parameters. Group C (no sepsis) comprised neonates with no clinical signs and no laboratory evidence of infection.

Statistical analysis

Data were entered and analysed using Microsoft Excel 2007 and SPSS version 16. Chi-square and Fisher's exact tests were used to assess the significance of associations between categorical variables. A p value of less than 0.05 was considered statistically significant. Diagnostic performance of PCT and CRP was assessed in terms of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV), using blood culture as the reference standard.

RESULTS

Demographic profile

A total of 75 neonates were enrolled over the 12-month study period. Of these, 46 (61.3%) were male and 29 (38.6%) were female, giving a male-to-female ratio of approximately 1.6:1. Thirty-nine neonates (52%) had a birth weight of less than 2.5 kg (low birth weight) and 36 (48%) had a birth weight of 2.5 kg or more. Regarding gestational age, 47 neonates (62.6%) were term (≥37 weeks) and 28 (37.3%) were preterm (<37 weeks).

Maternal risk factors

Among the maternal risk factors recorded, meconium-stained liquor (MSL) was the most common, present in 34 cases (45.3%), followed by prolonged rupture of membranes (PROM) in 19 cases (25.3%), prolonged or instrumental labour in 13 cases (17.3%), more than 3 vaginal examinations in 5 cases (6.6%), intrapartum fever (>38°F) in 2 cases (2.6%), maternal urinary tract

infection in 1 case (1.3%) and foul-smelling liquor in 1 case (1.3%). No case of documented maternal infection was recorded.

Clinical presentation

Respiratory system signs were the most frequently observed clinical feature, present in 42 cases (56%), followed by general symptoms such as lethargy and refusal to feed in 20 cases (26.6%), gastrointestinal features including vomiting and abdominal distension in 19 cases (25.3%), central nervous system signs in 15 cases (20%), cardiovascular signs in 5 cases (6.6%) and haematological manifestations in 3 cases (4%).

Blood culture results

Blood culture was positive in 7 of 75 cases (9.3%) and negative in the remaining 68 cases (90.6%). Among the positive cultures, coagulase-positive *Staphylococcus aureus* was isolated in 3 cases (42.8% of positive cultures), *Klebsiella* in 2 cases (28.5%), *Escherichia coli* in 1 case (14.3%) and *Pseudomonas* in 1 case (14.3%).

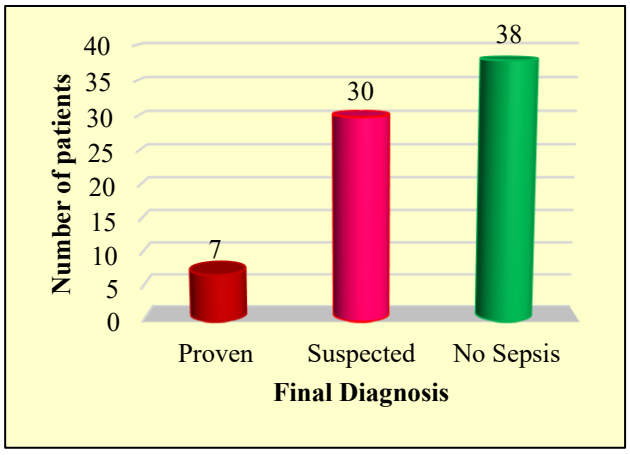

Figure 1: Final diagnosis of the patients.

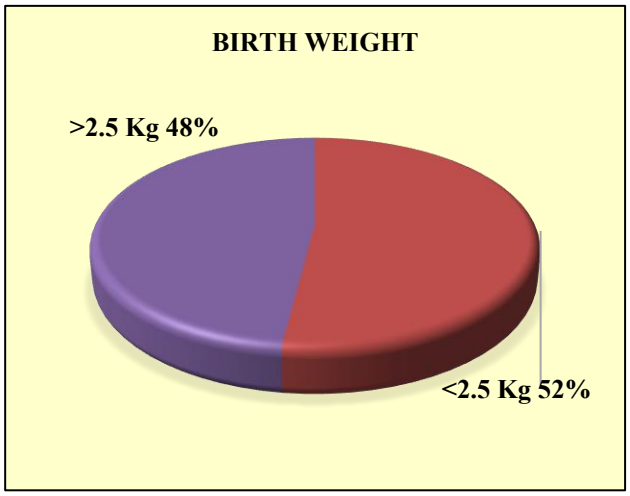

Figure 2: Distribution according to birth weight.

Haematological parameters

Total leukocyte count was below 5000/mm³ in only 1 case (1.3%); all remaining 74 cases (98.6%) had counts above 5000/mm³. Absolute neutrophil count was above 1800/mm³ in all 75 cases (100%). The I:T ratio exceeded 20% in only 1 case (1.3%). These haematological parameters were therefore largely unremarkable across the cohort and did not contribute substantially to sepsis identification in this study.

Final diagnosis

Based on the composite classification criteria, no sepsis was present in 38 cases (50.6%), suspected sepsis in 30 cases (40%) and proven sepsis in 7 cases (9.3%) (Figure 1).

Frequency distribution of procalcitonin and C-reactive protein

PCT was negative (<0.5 ng/ml) in 41 cases (54.6%) and positive (>0.5 ng/ml) in 34 cases (45.3%). Among PCT-positive cases, 13 (17.3%) had levels in the probable sepsis range (0.5–2.0 ng/ml) and 21 (28%) had levels in the definite sepsis range (>2.0 ng/ml). CRP was negative (<10 mg/l) in 61 cases (81.3%) and positive (≥10 mg/l) in 14 cases (18.6%).

Diagnostic performance of procalcitonin and C-reactive protein

Using blood culture as the reference standard, PCT demonstrated a sensitivity of 85.7%, specificity of 58.8%, PPV of 17.6% and NPV of 97.5%. CRP demonstrated a sensitivity of 42.8%, specificity of 83.8%, PPV of 21.4% and NPV of 93.4%. These results are summarised in Table 1.

Cross-comparison of procalcitonin and C-reactive protein

When PCT was evaluated in relation to CRP positivity (i.e., using CRP as the reference), PCT showed a sensitivity of 85.7%, specificity of 63.9%, PPV of 35.2% and NPV of 95.1%. When CRP was evaluated in relation to PCT positivity, CRP showed a sensitivity of 35.2%, specificity of 95.1%, PPV of 85.7% and NPV of 63.9%. This is detailed in Table 2.

Subgroup analysis: gender

Among 46 male neonates, PCT was positive in 23 cases (50%) compared to CRP which was positive in only 12 cases (26.08%). The difference in positivity between PCT and CRP among males was statistically significant (p=0.007). Among 29 female neonates, PCT was positive in 11 cases (37.9%) and CRP in 2 cases (6.8%), but this difference did not reach statistical significance (p=0.135).

Subgroup analysis: gestational age

Among 47 term neonates (≥37 weeks), PCT was positive in 20 cases (42.5%) compared to 9 cases (19.1%) for CRP; this difference was statistically significant (p=0.003). Among 28 preterm neonates, PCT was positive in 14 cases (50%) and CRP in 5 cases (17.8%), but the difference was not statistically significant (p=0.326).

Subgroup analysis: birth weight

Among 36 normal birth weight neonates (≥2.5 kg) (Figure 2), PCT was positive in 16 cases (44.4%) versus CRP in 8 cases (22.2%); the difference was highly significant (p=0.000). Among 39 low birth weight neonates (<2.5 kg), PCT was positive in 18 cases (46.1%) and CRP in 6 cases (15.3%), but the difference was not statistically significant (p=0.387).

Association of maternal risk factors with procalcitonin and C-reactive protein positivity

With respect to maternal risk factors, PCT positivity was observed in 100% of cases with foul-smelling liquor (1/1), 100% of cases with maternal UTI (1/1), 80% of cases with more than 3 vaginal examinations (4/5), 50% of cases with intrapartum fever (1/2), 44.1% of cases with meconium-stained liquor (15/34), 42.1% of cases with PROM (8/19) and 30.7% of cases with prolonged or instrumental labour (4/13). For CRP, positivity rates were lower across all risk factor categories: 100% for foul-smelling liquor (1/1), 40% for more than 3 vaginal examinations (2/5), 23.07% for prolonged labour (3/13), 21.05% for PROM (4/19) and 11.7% for meconium-stained liquor (4/34). No CRP positivity was observed in cases with maternal UTI or intrapartum fever. None of these associations reached statistical significance (p >0.05 for all), likely reflecting the small numbers in individual risk-factor categories.

Table 1: Diagnostic performance of PCT and CRP against blood culture.

Marker (Cut-off)	Sensitivity	Specificity	PPV	NPV
PCT (>0.5 ng/ml)	85.7%	58.8%	17.6%	97.5%
CRP (≥10 mg/l)	42.8%	83.8%	21.4%	93.4%

Table 2: Cross-comparison of PCT and CRP positivity.

Parameter	PCT vs CRP (PCT as index)	CRP vs PCT (CRP as index)
True positive	12	12
False positive	22	2
False negative	2	22
True negative	39	39
Sensitivity	85.7%	35.2%
Specificity	63.9%	95.1%
PPV	35.2%	85.7%
NPV	95.1%	63.9%

DISCUSSION

Neonatal sepsis continues to pose a formidable diagnostic and therapeutic challenge in developing countries. The combination of non-specific clinical presentation, limited sensitivity of conventional haematological parameters and the inherent delay associated with blood culture results underscores the need for reliable biochemical markers that can guide early antibiotic therapy.[1,2] This study sought to evaluate and compare the diagnostic utility of PCT and CRP for early onset neonatal sepsis in a tertiary NICU setting.

Demographic findings

The male predominance (61.3%) observed in this study is consistent with previously reported data. Tallur et al reported 63% males among 242 neonates with septicaemia in Hubli, India and Khinchi et al reported 65.9% males in their series of 411 neonates.[11,12] This male preponderance is widely attributed to X-linked immunoregulatory genes that render male neonates more susceptible to infections. Additionally, health-seeking behaviour favoring male children in the region may contribute to a higher proportion of male admissions in Indian NICUs. The high proportion of low-birth-weight neonates (52%) is consistent with Tallur et al (54.5%), reflecting the well-established relationship between low birth weight and immune vulnerability, including impaired neutrophil function, hypogammaglobulinemia and reduced complement activity.[12]

Maternal risk factors and microbiology

Meconium-stained liquor was the most frequent maternal risk factor (45.3%), comparable to Raghavan et al (46%). PROM occurred in 25.3% of cases, higher than Tallur et al, (14.05%) Kuruvilla et al (13.3%) possibly reflecting

differences in obstetric care practices.[11,13,14] Blood culture positivity of 9.3% is consistent with comparable studies Rodwell et al reported 9% and Boyle et al reported 8%.[15,16] The low yield reflects the well-known limitations of blood cultures in neonates, including small sample volumes, transient bacteraemia and the frequent prior use of antibiotics. The predominance of *S. aureus* and *Klebsiella* as causative organisms aligns with the Indian neonatal sepsis literature and differs from the GBS-dominant pattern seen in developed countries, an important consideration when interpreting PCT reference values derived from Western studies.[4]

Diagnostic performance of C-reactive protein

At a cut-off of 10 mg/l, CRP demonstrated a sensitivity of 42.8%, specificity of 83.8%, PPV of 21.4% and NPV of 93.4% in this study. These findings are consistent with those of Joram et al (sensitivity 50%, specificity 97%) and Bonac et al (sensitivity 36%, specificity 92% at a 14 mg/l cut-off).[17,18] The relatively low sensitivity of CRP, particularly within the first 72 hours, reflects its delayed synthesis in response to cytokine stimulation.[5] Since CRP transcription is directed by cytokines released only hours after the infective stimulus, its diagnostic window is inherently late. Serial CRP measurements at 24 and 48 hours have been shown to improve sensitivity to 82–84%, but such a strategy is not useful at the time of initial clinical presentation when a treatment decision must be made.[5,6]

Diagnostic performance of C-reactive protein

PCT demonstrated a sensitivity of 85.7%, specificity of 58.8%, PPV of 17.6% and NPV of 97.5% in this study. The sensitivity is consistent with Joram et al (87.5%) and higher than Pamela et al (57%), while the lower specificity compared to CRP (58.8% vs. 83.8%) has been reported by other investigators, including Janota et al and Naher et al.[17,19-21] The reduced specificity of PCT can partly be attributed to physiological post-natal PCT elevations healthy term neonates exhibit a transient rise in PCT in the first 48 hours of life due to birth-related stress, perinatal asphyxia and respiratory distress syndrome (RDS). Lapillone et al also noted falsely elevated PCT in preterm neonates with RDS and haemodynamic failure.[22] However, since this study enrolled only neonates with clinical suspicion or risk factors for sepsis, the clinical context already filters out completely healthy neonates, making the specificity profile more relevant.

The high NPV of PCT (97.5%) is its most clinically significant attribute. In the NICU context, where the consequences of untreated sepsis are severe, a test with high NPV allows the clinician to confidently withhold antibiotics in the majority of neonates with a negative result. This has the dual benefit of reducing unnecessary antibiotic exposure with its attendant risks of antibiotic resistance, gut microbiome disruption and adverse drug effects and reducing healthcare costs. Koksal et al have similarly concluded that serum PCT is superior to CRP in early diagnosis of neonatal sepsis, detection of disease severity and monitoring the antibiotic response, further supporting the findings of this study.[23]

Comparative performance and combined use

When PCT and CRP are evaluated in cross-comparison, PCT's high sensitivity (85.7%) and NPV (95.1% in relation to CRP) make it the superior test for ruling out sepsis, while CRP's high specificity (95.1% in cross-comparison with PCT) and PPV (85.7%) make it the better test for ruling in sepsis. This complementary relationship has important clinical implications: a negative PCT effectively excludes sepsis and supports a decision to withhold antibiotics, while an elevated CRP in the context of clinical signs strongly supports the diagnosis of sepsis. Several investigators, including Muller et al and Ng et al have advocated combined PCT and CRP use and the results of this study provide further empirical support for such a strategy.[24,25]

Subgroup analysis

The significantly higher PCT positivity compared to CRP in term neonates (p=0.003) and normal birth weight neonates (p=0.000) is a notable finding. Much of the published literature has focused on PCT's diagnostic value in preterm and very low birth weight neonates, where physiological PCT elevations complicate interpretation. The significant advantage of PCT in term and appropriate-for-gestational-age neonates is less widely reported. Fendler et al demonstrated PCT as a valuable diagnostic tool specifically in preterm neonates with nosocomial sepsis, while Lachowska et al found significantly higher PCT in infected preterm neonates compared to uninfected controls.[26,27] In the present study, while PCT showed numerically higher positivity in preterm neonates (50% vs. 17.8%), the difference did not reach statistical significance (p=0.326), possibly due to the relatively small preterm subgroup. The significant male preponderance of PCT positivity (p=0.007) has not been extensively described in the literature and warrants further investigation in larger studies.

Limitations

This study has several limitations. The sample size of 75, while adequate for primary analysis, limits the power of subgroup analyses, particularly for the preterm and low birth weight cohorts.

As a single-centre study, the findings may not be generalisable to all Indian NICU settings. Blood culture, used as the reference standard, has inherent limitations in sensitivity, meaning some true cases of sepsis may have been misclassified as suspected or no sepsis. The study did not perform serial PCT measurements at 24 and 48 hours, which may have provided additional diagnostic information. Furthermore, the physiological post-natal

PCT reference ranges used were derived from Western populations and may require adaptation for the Indian neonatal context.

CONCLUSION

Procalcitonin is a superior early biomarker for neonatal sepsis compared with CRP, owing to its higher sensitivity and excellent negative predictive value. A negative PCT can reliably help rule out early onset sepsis and may reduce unnecessary antibiotic use in NICU settings. CRP, with higher specificity, remains useful as a complementary marker for confirmation when interpreted with clinical findings. Therefore, incorporating PCT into the routine neonatal sepsis screen, alongside CRP and blood culture, may improve early diagnosis, guide rational antibiotic therapy and reduce treatment burden.

The significant performance of PCT among term, normal birth weight and male neonates further supports its usefulness across a broader neonatal population. Although cost may limit routine use, its potential to reduce prolonged hospitalization and irrational antibiotic exposure makes it clinically valuable. Wider implementation of PCT-based sepsis screening protocols may strengthen antimicrobial stewardship in neonatal care. Larger multicentre studies are needed to validate these findings and define neonatal reference ranges.

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