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Diagnostic Accuracy of Platelet Count and Platelet Indices in Neonatal Sepsis at a Tertiary Care Hospital

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Abstract

Neonatal sepsis remains a major contributor to neonatal morbidity and mortality, particularly in resource-limited settings. Limited access to advanced diagnostic facilities and nonspecific clinical signs often make early diagnosis challenging. This study aimed to evaluate the diagnostic accuracy of platelet count and platelet indices in neonates with suspected sepsis admitted to a tertiary-care hospital. A cross-sectional diagnostic validation study was conducted in the Department of Paediatrics, Ittefaq Hospital (Trust), Lahore, from June 2025 to December 2025. A total of 170 neonates aged 1–28 days who presented with suspected sepsis were enrolled. Venous blood specimens were analyzed for platelet parameters, and blood cultures were obtained to confirm infection. Total platelet count (TPC) <150,000/μL, mean platelet volume (MPV) $\geq$9 fL, and an MPV/TPC ratio $\geq$7.2 were evaluated using predefined diagnostic thresholds. Diagnostic performance was assessed in terms of sensitivity, specificity, predictive values, overall accuracy, and receiver operating characteristic (ROC) analysis. Of the 170 neonates, 75 (44.1%) were culture-positive. TPC showed high specificity (95.8%) but relatively low sensitivity (42.7%), whereas MPV was more sensitive (68.0%) but less specific (58.9%). The MPV/TPC ratio achieved a specificity of 94.7%, a sensitivity of 50.7%, an overall diagnostic accuracy of 75.3%, and the highest area under the ROC curve (0.76). All three platelet measurements showed potential value as rapid, readily available, and inexpensive adjuncts for assessing neonatal sepsis. Their moderate sensitivity indicates, however, that none should replace microbiological confirmation or careful clinical evaluation. These findings support additional validation before incorporation of specific platelet thresholds into routine clinical decision-making.

Keywords: Neonatal Sepsis, Platelet Count, Mean Platelet Volume, MPV/TPC Ratio, Diagnostic Accuracy, Hematological Markers

1. INTRODUCTION

Neonatal sepsis is a systemic infection associated with a dysregulated host inflammatory response and remains a major cause of neonatal morbidity and mortality worldwide. The condition can affect multiple organ systems and may produce substantial hematological and hemostatic alterations, including changes in platelet count and platelet indices [1]. In low- and middle-income countries, limitations in diagnostic capacity and delays in initiating appropriate treatment may contribute to unfavorable clinical outcomes [2, 3]. According to successive Pakistan Demographic and Health Surveys, the neonatal mortality rate declined from 55 deaths per 1,000 live births in 2012–2013 to 42 per 1,000 live births in 2017–2018; nevertheless, neonatal infections remain an important cause of preventable mortality in Pakistan [4, 2]. Prompt diagnosis, appropriate treatment, and timely recognition of severe infection are therefore essential elements of neonatal care, particularly in hospitals serving populations with limited access to specialized diagnostic facilities [1, 5].

Early diagnosis of neonatal sepsis remains challenging because its clinical manifestations are nonspecific and may resemble those of noninfectious conditions in newborn infants. Blood culture is an established reference investigation for detecting bacterial bloodstream infection; however, its clinical utility may be limited by the time required to obtain results, the small volume of blood collected, prior antimicrobial exposure, and reduced sensitivity in some clinical circumstances [6]. Consequently, simple laboratory measurements that can be obtained rapidly and at relatively low cost are needed to support early clinical decisions while microbiological investigations are pending. Such measurements may contribute useful supplementary evidence, although they should not replace careful clinical assessment or blood culture [3, 7].

Platelets are essential components of hemostasis and also participate in inflammation, innate immune responses, and host defense against infection. During neonatal sepsis, increased platelet consumption, alterations in platelet production, and inflammation-related activation may contribute to thrombocytopenia and changes in platelet indices. Total platelet count (TPC) is routinely measured as part of the complete blood count, while mean platelet volume (MPV) provides information about average platelet size and may reflect changes in platelet turnover and activity. The MPV/TPC ratio has likewise been investigated as a potential diagnostic indicator of neonatal sepsis. Because these measurements are comparatively inexpensive, widely available, and often reported by routine hematology analyzers, they may be particularly practical in resource-constrained healthcare settings [8, 9, 10].

Previous investigations have demonstrated substantial variation in the diagnostic performance of these platelet parameters. In a study involving 97 neonates, 43 (44%) had culture-confirmed sepsis. At a TPC threshold of 150,000/μL, sensitivity and specificity were 41.5% and 96.15%, respectively. For MPV at a threshold of $\geq$9 fL, the corresponding values were 63.40% and 53.8%. An MPV/TPC ratio of $\geq$7.2 showed a sensitivity of 48.8% and a specificity of 96.22% [11]. In another study, an MPV threshold of 10.2 fL yielded a sensitivity of 71% and a specificity of 63% [12]. At an MPV threshold of 10.35 fL, a separate investigation reported a sensitivity of 97.8% and a specificity of 78.7% [13]. These differences suggest that the diagnostic usefulness of platelet indices depends on the population examined, the selected cut-off values, the analytical methods employed, and the clinical setting in which testing is performed.

Because the findings of previous studies have not been entirely consistent, the diagnostic performance of each platelet parameter requires evaluation in the local neonatal population before routine interpretation of a particular threshold. Differences in gestational maturity, severity of illness, laboratory practice, and patterns of neonatal infection may influence the usefulness of these measurements. Evaluation in a tertiary-care hospital in Pakistan is therefore relevant to determining how readily available hematological investigations may contribute to decision-making in everyday clinical practice.

Accordingly, the present study aimed to determine the diagnostic performance of TPC, MPV, and the MPV/TPC ratio among neonates admitted with suspected neonatal sepsis, using blood culture as the reference standard. It also sought to clarify the potential contribution of these readily available hematological parameters as supplementary investigations alongside conventional diagnostic procedures. Particular attention was given to their sensitivity, specificity, predictive values, and ability to distinguish culture-positive from culture-negative neonates in a resource-constrained clinical setting.

The primary objective of this research was to assess the diagnostic accuracy of platelet count and platelet indices for identifying neonatal sepsis in newborn infants admitted to a tertiary-care hospital, and to compare the clinical performance of the individual platelet measurements with that of the MPV/TPC ratio.

2. METHODOLOGY

This cross-sectional diagnostic validation study was conducted in the Department of Paediatrics, Ittefaq Hospital (Trust), Lahore, Pakistan, from June 2025 to December 2025. The calculated sample size was 170 neonates, based on previously reported sensitivity and specificity estimates of 63.4% and 53.8%, respectively, a margin of error of 11%, and a 95% confidence level. Eligible patients were recruited through a nonprobability consecutive sampling procedure. All included neonates underwent clinical examination and laboratory evaluation of platelet parameters, together with blood culture for the identification of culture-confirmed sepsis. Diagnostic classification by TPC, MPV, and the MPV/TPC ratio was compared with culture findings using two-by-two contingency tables and receiver operating characteristic (ROC)

analysis. This approach permitted estimation of the diagnostic performance of each routinely available platelet measurement.

Neonates of either sex, aged 1–28 days, were eligible when they presented with clinical features suggestive of sepsis, including fever (temperature >38°C), reduced spontaneous movements, difficulty in suckling or feeding, bradycardia, tachycardia, or abdominal discomfort or pain observed during clinical examination. The presence of these clinical findings prompted investigation for suspected infection according to the study's selection criteria.

Neonates with chromosomal aneuploidies, hydrops fetalis, hypoxic–ischemic encephalopathy, intrauterine growth restriction, polycythemia, hemolytic anemia, or a previous history of platelet transfusion were excluded from the study. Additional exclusion criteria concerned maternal conditions that could affect neonatal hematological findings. These included a maternal history of idiopathic thrombocytopenic purpura, collagen vascular disease, gestational hypertension (blood pressure $\geq$140/90 mmHg), or a documented maternal infection with toxoplasmosis, rubella, cytomegalovirus, or herpes during pregnancy. These criteria were applied during enrollment to reduce potential interference with platelet-related measurements.

Following institutional ethical approval, 170 neonates were recruited from the paediatric emergency department. Informed consent was obtained from the parents or legal guardians before participation. Demographic and clinical variables were recorded, including postnatal age, sex, current weight, birth weight, gestational age, mode and place of delivery, Apgar score, socioeconomic status, and family history of sepsis. A 5-mL venous blood specimen was collected under aseptic conditions and promptly transported to the hospital laboratory for hematological analysis and blood culture. The laboratory assessment included total platelet count, mean platelet volume, and calculation of the MPV/TPC ratio, while blood culture was undertaken concurrently to confirm bacterial infection. Results were reviewed and neonates were classified as positive or negative for each platelet parameter according to the predefined diagnostic thresholds. Culture findings served as the reference classification for sepsis. All demographic details, clinical observations, laboratory measurements, and culture outcomes were entered into a structured study proforma.

Study data were entered and analyzed using IBM SPSS Statistics, version 26. Continuous variables, including age, current and birth weights, gestational age, and Apgar score, were summarized as mean values $\pm$ standard deviations. Categorical variables, including sex, mode and place of delivery, residence, socioeconomic status, and family history, were presented as frequencies and percentages. Separate two-by-two contingency tables were constructed for TPC, MPV, and the MPV/TPC ratio against the blood-culture reference results. These tables were used to calculate sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy for each parameter. ROC curves were evaluated and the area under each curve (AUC) was estimated to describe diagnostic discrimination. Statistical significance was assessed using a two-sided threshold of $p < 0.05$, and the reported analyses were interpreted in relation to the clinical context.

3. RESULTS

A total of 170 neonates aged 1–28 days who presented with clinical features of suspected sepsis were included in the study. The diagnostic value of total platelet count (TPC), mean platelet volume (MPV), and the MPV/TPC ratio was assessed against blood-culture findings. The mean postnatal age of the enrolled neonates was 8.6 $\pm$ 6.2 days. Among the participants, 75 neonates (44.1%) had culture-confirmed sepsis, whereas the remaining 95 neonates (55.9%) were culture-negative. The demographic and clinical characteristics of both groups are compared in Table 1.

Table 1. *Demographic and Clinical Characteristics of Study Neonates (n=170)*

Characteristic	Total (n=170)	Culture Positive (n=75)	Culture Negative (n=95)	p-value
Age (days), mean $\pm$ SD	8.6 $\pm$ 6.2	7.9 $\pm$ 5.8	9.1 $\pm$ 6.5	0.21
Male gender, n (%)	92 (54.1%)	43 (57.3%)	49 (51.6%)	0.46
Birth weight (kg), mean $\pm$ SD	2.68 $\pm$ 0.54	2.55 $\pm$ 0.51	2.78 $\pm$ 0.55	0.008
Gestational age (weeks), mean $\pm$ SD	37.2 $\pm$ 2.1	36.8 $\pm$ 2.3	37.5 $\pm$ 1.9	0.04
Cesarean delivery, n (%)	98 (57.6%)	46 (61.3%)	52 (54.7%)	0.39

As shown in Table 1, male neonates and those delivered by cesarean section constituted the larger proportions of the sample. Culture-positive neonates had a significantly lower mean birth weight than culture-negative neonates ($p = 0.008$), together with a lower mean gestational age ($p = 0.04$). No statistically significant differences were observed between the groups in postnatal age, sex distribution, or mode of delivery. These findings describe the principal demographic and perinatal characteristics of the participating neonates.

Table 2. *Comparison of Platelet Parameters Between Culture-Positive and Culture-Negative Neonates*

Parameter	Culture Positive (n=75)	Culture Negative (n=95)	p-value
TPC ($\times 10^3/\mu$L), mean $\pm$ SD	132 $\pm$ 48	245 $\pm$ 62	<0.001
MPV (fL), mean $\pm$ SD	10.1 $\pm$ 1.3	8.4 $\pm$ 1.1	<0.001
MPV/TPC ratio, mean $\pm$ SD	8.9 $\pm$ 3.2	3.7 $\pm$ 1.4	<0.001
TPC <150000/μL, n (%)	32 (42.7%)	4 (4.2%)	<0.001
MPV $\geq$9 fL, n (%)	51 (68.0%)	39 (41.1%)	<0.001
MPV/TPC $\geq$7.2, n (%)	38 (50.7%)	5 (5.3%)	<0.001

Table 2 compares the hematological measurements between the two study groups. Culture-positive neonates had a significantly lower mean TPC, whereas their mean MPV and MPV/TPC ratio were significantly higher than those of culture-negative neonates. Similarly, the proportions of neonates meeting each predefined abnormal platelet threshold differed significantly between the groups. All of the reported comparisons of platelet parameters were statistically significant ($p < 0.001$), indicating substantial differences in platelet-related measurements according to culture status.

Table 3. *Diagnostic Performance of TPC, MPV, and MPV/TPC Ratio Against Blood Culture*

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic Accuracy (%)
TPC <150000/μL	42.7	95.8	88.9	67.9	72.4
MPV $\geq$9 fL	68.0	58.9	56.7	70.0	62.9
MPV/TPC $\geq$7.2	50.7	94.7	88.4	70.9	75.3

The diagnostic performance estimates derived from the corresponding two-by-two contingency tables are presented in Table 3. TPC and the MPV/TPC ratio showed high specificity and positive predictive values at the selected thresholds, suggesting that positive findings could support a clinical suspicion of sepsis. By comparison, MPV showed greater sensitivity but lower specificity. The highest reported overall diagnostic accuracy was achieved by the MPV/TPC ratio, followed by TPC and then MPV; nevertheless, none of these measurements was sufficiently sensitive to exclude sepsis when negative.

Table 4. *Receiver Operating Characteristic (ROC) Analysis of Platelet Parameters*

Parameter	Area Under Curve (AUC)	95% Confidence Interval	p-value
TPC	0.71	0.63 – 0.79	<0.001
MPV	0.68	0.60 – 0.76	<0.001
MPV/TPC ratio	0.76	0.69 – 0.83	<0.001

The results of the receiver operating characteristic analysis are summarized in Table 4. All three parameters demonstrated statistically significant discriminatory ability for culture-confirmed neonatal sepsis. Among the investigated markers, the MPV/TPC ratio produced the highest AUC, indicating the strongest overall discrimination in this sample. TPC and MPV also showed moderate discrimination, although their diagnostic properties differed from those of the ratio. The reported AUC values and confidence intervals should be considered together with the sensitivity and specificity estimates when assessing potential clinical usefulness.

Of the 170 neonates with suspected sepsis, 75 (44.1%) were confirmed as culture-positive. Overall, platelet count was substantially lower in the culture-positive group, while MPV and the MPV/TPC ratio were higher. Both TPC and the MPV/TPC ratio showed specificity above 94%, whereas MPV produced the highest sensitivity, at 68.0%. The MPV/TPC ratio also yielded the greatest overall diagnostic accuracy (75.3%) and the largest area under the ROC curve (0.76). These results support the potential value of readily available platelet indices as rapid, supplementary hematological markers during the initial assessment of suspected neonatal sepsis in a tertiary-care setting.

4. DISCUSSION

Neonatal sepsis remains an important cause of morbidity and mortality worldwide, particularly in low- and middle-income countries where access to early diagnostic testing may be limited [1]. The condition involves systemic inflammatory responses to infection and can result in organ dysfunction as well as characteristic hematological abnormalities [6]. Because neonatal immune defenses are immature, newborn infants, especially those born preterm or with a low birth weight, may be particularly vulnerable to serious infection [14]. In addition to maintaining hemostasis, platelets contribute to innate immunity, inflammatory signaling, and vascular integrity during an infectious response [5]. Thrombocytopenia in sepsis can reflect increased platelet consumption, endothelial activation, and the effects of inflammatory mediators [8].

Compensatory changes in platelet production and turnover may also alter the average size of circulating platelets, thereby affecting both total platelet count (TPC) and mean platelet volume (MPV) [9].

Early identification of neonatal sepsis is difficult because clinical findings such as temperature instability, lethargy, poor feeding, and respiratory disturbances are nonspecific and frequently overlap with those of other neonatal disorders [6]. Blood culture remains an important reference investigation for bloodstream infection, but delayed availability of results, limited specimen volume, low bacterial concentrations, and antimicrobial exposure can restrict its sensitivity and timeliness [1]. In resource-limited hospitals, these constraints may contribute to delays in appropriate treatment and may also encourage prolonged empirical antibiotic exposure when infection has not been confirmed [3]. Rapid, inexpensive, and accessible hematological measurements can therefore offer supplementary information for the early recognition of suspected sepsis, provided that their diagnostic limitations are properly understood [7, 9].

The present investigation included 170 neonates with suspected sepsis, of whom 75 (44.1%) had positive blood cultures. As detailed in Table 1, the mean birth weight of culture-positive neonates was significantly lower than that of culture-negative neonates (2.55 ± 0.51 kg compared with 2.78 ± 0.55 kg; $p = 0.008$). Mean gestational age was also lower in the culture-positive group (36.8 ± 2.3 weeks versus 37.5 ± 1.9 weeks; $p = 0.04$). These observations are consistent with previous evidence identifying prematurity and low birth weight as relevant factors in the vulnerability of neonates to infection [14]. However, associations observed in this cross-sectional study should not be interpreted as proof of a direct causal relationship between these perinatal characteristics and sepsis.

Substantial differences were observed in the hematological measurements of the two groups, as presented in Table 2. Mean TPC was significantly lower in culture-positive neonates than in culture-negative neonates ($132 \pm 48 \times 10^3/\mu$L versus $245 \pm 62 \times 10^3/\mu$L; $p < 0.001$). Conversely, mean MPV was higher among culture-positive neonates (10.1 ± 1.3 fL versus 8.4 ± 1.1 fL; $p < 0.001$). The MPV/TPC ratio was likewise elevated in the infected group (8.9 ± 3.2 compared with 3.7 ± 1.4; $p < 0.001$). These differences indicate that platelet size and platelet count varied systematically with culture-confirmed sepsis in this sample. Such a pattern may reflect increased peripheral platelet consumption alongside changes in platelet turnover and production, supporting investigation of routine platelet measurements as adjunctive diagnostic indicators [15].

The performance of the investigated parameters varied considerably, as shown in Table 3 and Table 4. At a TPC threshold of <150,000/μL, sensitivity was 42.7% and specificity was 95.8%, with a positive predictive value (PPV) of 88.9%, an overall diagnostic accuracy of 72.4%, and an AUC of 0.71. The high specificity suggests that the presence of thrombocytopenia may provide supportive evidence when sepsis is suspected clinically. However, sensitivity at this threshold was relatively low, meaning that many culture-positive neonates would not be identified on the basis of platelet count alone. A platelet count above the selected threshold therefore cannot reliably exclude infection and should not be used as an isolated rule-out test.

At the selected threshold of MPV $\geq$9 fL, the sensitivity was 68.0%, which was higher than that of the other two investigated platelet parameters, while specificity was lower at 58.9%. Overall diagnostic accuracy was 62.9%, and the estimated AUC was 0.68. These findings indicate that MPV may detect a greater proportion of culture-positive neonates than the selected platelet-count threshold, but its relatively low specificity limits its usefulness as an independent diagnostic test. Increased MPV may arise from enhanced platelet turnover and thrombopoiesis during infection; nevertheless, other inflammatory conditions and physiological influences may also affect platelet size. Previous investigations have likewise reported variations in the diagnostic performance of MPV across neonatal populations and analytical settings [16].

The MPV/TPC ratio showed the highest overall diagnostic accuracy among the three investigated parameters. At a threshold of $\geq$7.2, sensitivity was 50.7%, specificity was 94.7%, PPV was 88.4%, negative predictive value (NPV) was 70.9%, and overall diagnostic accuracy was 75.3%. Its AUC of 0.76 was also higher than the reported values for TPC and MPV individually, indicating stronger overall discrimination in the study sample. This ratio incorporates two potentially complementary hematological changes, namely an increase in platelet volume and a reduction in platelet count. Their combined expression may help distinguish culture-positive from culture-negative neonates more effectively than either measurement alone. However, sensitivity remained moderate, indicating that the ratio cannot independently rule out neonatal sepsis or replace appropriate microbiological testing.

The findings of this study are broadly comparable with those of the investigation involving 97 neonates with suspected sepsis [11]. In that study, TPC had a sensitivity of 41.5% and a specificity of 96.15%, while MPV showed a sensitivity of 63.4% and a specificity of 53.8%. At a threshold of $\geq$7.2, the MPV/TPC ratio achieved a sensitivity of 48.8% and a specificity of 96.22%. The results are reasonably consistent with those observed in the present sample, particularly regarding the comparatively high specificity and moderate-to-low sensitivity of the platelet count and ratio. Differences in case selection, patient characteristics, laboratory methodology, and the clinical severity of infection may account for variations between investigations. Nevertheless, the overall similarity supports further evaluation of the MPV/TPC ratio as a supplementary diagnostic indicator.

Other investigations have also reported variation in the performance of platelet measurements during neonatal infec-

tion. Studies involving preterm neonates have demonstrated differences in MPV values and diagnostic utility, which may be influenced by gestational maturity, infection severity, blood-sampling intervals, and the characteristics of hematology analyzers [17]. Systematic reviews and meta-analyses have identified a potential diagnostic role for MPV while also emphasizing differences in study populations, measurement methods, and the thresholds applied to define abnormal results [16, 15]. Additional research has examined combinations of laboratory biomarkers for improving early identification of culture-positive neonatal sepsis [18]. These findings suggest that cut-off points developed in a single clinical population should undergo external validation before routine application in another patient population.

The principal practical advantage of platelet indices in resource-limited hospitals is that they can usually be obtained from the complete blood count (CBC), which is already performed routinely during the evaluation of suspected infection. Consequently, the parameters may provide useful information without requiring substantial additional laboratory resources or highly specialized investigations. They can help guide clinical assessment while definitive microbiological findings are pending, although their diagnostic limitations must be acknowledged. The moderate sensitivities observed in this study indicate that platelet indices alone are insufficient to confirm or exclude neonatal sepsis. Their appropriate role is therefore as supplementary measurements that should be interpreted in conjunction with clinical findings, blood culture, and other laboratory investigations.

Additional measures derived from the complete blood count, including the neutrophil-to-lymphocyte ratio and platelet-to-lymphocyte ratio, have also been investigated as potential diagnostic indicators for neonatal infection [19, 20]. Such measures may contribute further information when interpreted alongside conventional inflammatory biomarkers and the clinical presentation, particularly in selected neonatal populations [18]. For neonates with persistent clinical suspicion despite negative culture results, serial platelet counts, C-reactive protein (CRP) measurements, and repeated clinical examinations may assist in ongoing evaluation [21]. Appropriate identification of maternal and neonatal risk factors also remains important for recognizing vulnerable patients, guiding timely treatment, and reducing avoidable complications associated with infection [14, 6].

Overall, the study demonstrated significant differences in TPC, MPV, and the MPV/TPC ratio between culture-positive and culture-negative neonates. The MPV/TPC ratio produced the highest overall diagnostic accuracy and AUC, whereas a TPC below 150,000/μL had the highest specificity among the investigated thresholds. Taken together, these results suggest that platelet indices can provide useful supplementary evidence during the assessment of suspected neonatal sepsis. Nevertheless, because sensitivity was only moderate, none of the parameters should be relied upon as a stand-alone diagnostic investigation. Further prospective investigations and external validation are required to establish dependable thresholds, clarify the effects of clinical and laboratory variation, and determine whether adding platelet indices to clinical assessment and other biomarkers improves diagnostic decisions. These inexpensive and readily accessible measurements may support earlier risk stratification and more informed antimicrobial management, but their interpretation should remain integrated with clinical evaluation and microbiological testing.

5. CONCLUSION

Total platelet count and platelet indices, particularly the MPV/TPC ratio, demonstrated potential clinical usefulness as supplementary indicators in the early assessment of neonatal sepsis. MPV showed the highest sensitivity among the evaluated parameters, whereas TPC and the MPV/TPC ratio showed comparatively high specificity at the thresholds investigated. Because these measurements are readily obtainable from routine complete blood counts, they may offer a practical and inexpensive additional source of diagnostic information in resource-limited healthcare settings. Their incorporation into diagnostic assessment may help clinicians recognize suspected infection and guide decisions while culture results are pending. However, none of these parameters can replace blood culture or comprehensive clinical assessment, and clinical benefits should not be assumed solely from diagnostic accuracy estimates. Implementation of local testing protocols should therefore be considered only after appropriate validation of the proposed thresholds and further evaluation of their effects on clinical outcomes.

Author Contributions

All authors contributed equally to the study conception and design, preparation and critical revision of the manuscript. All authors reviewed the completed manuscript, approved the final version for publication, and agreed to be accountable for their respective contributions.

Conflicts of Interest

The authors declare that they have no financial or nonfinancial competing interests relevant to this work.

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Data Availability

The availability of the study data is subject to institutional policies, ethical approval conditions, and protection of participant confidentiality. Requests for access should be directed to the corresponding author and considered in accordance with applicable institutional requirements.

Ethics Approval and Consent to Participate

The study was conducted after obtaining institutional ethical approval. Informed consent for participation was obtained from the parents or legal guardians of the enrolled neonates.

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