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Research Article

Diagnostic Efficacy of Cerebrospinal Fluid Procalcitonin as a Novel Biomarker in Neonatal Bacterial Meningitis: An Original Observational Study

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Abstract

Background: Neonatal meningitis remains a critical pediatric emergency associated with high mortality and severe neurological sequelae. Because conventional cerebrospinal fluid (CSF) parameters and blood cultures often present diagnostic dilemmas—especially in preterm infants or following traumatic lumbar punctures—reliable early biomarkers are urgently required. This study evaluates the diagnostic performance of CSF Procalcitonin (PCT) in distinguishing neonatal bacterial meningitis from non-meningitis cases. Methods: A hospital-based prospective observational study was conducted in the neonatal intensive care unit (NICU) of a tertiary care teaching hospital over a one-year period (November 2019 to October 2020). A total of 43 neonates presenting with suspected sepsis or meningitis underwent evaluation, including lumbar puncture for cytological, biochemical, and quantitative chemiluminescent CSF Procalcitonin analysis. Results: Among the 43 enrolled subjects, 22 were diagnosed with meningitis and 21 served as non-meningitis controls based on standardized diagnostic criteria. CSF PCT levels were significantly elevated in the meningitis group compared to controls (mean 0.48 ± 0.37 ng/mL vs. 0.08 ± 0.20 ng/mL, p = 0.0015). Receiver Operating Characteristic (ROC) curve analysis demonstrated an area under the curve (AUC) of 0.789 (95% CI: 0.645–0.933, p = 0.001) for CSF PCT. At an optimal cut-off value of 0.13 ng/mL, CSF PCT exhibited a sensitivity of 86.36%, specificity of 23.81%, positive predictive value of 54.29%, and negative predictive value of 62.50%. Traditional parameters such as CSF protein and total leukocyte count also showed significant elevation in the meningitis group. Conclusion: CSF Procalcitonin is a valuable adjunctive biomarker for diagnosing neonatal bacterial meningitis. Its quantitative measurement is particularly useful in ambiguous clinical scenarios, such as traumatic lumbar punctures or culture-negative cases, aiding timely therapeutic decision-making.

Keywords: *Neonatal Meningitis; Cerebrospinal Fluid; Procalcitonin; Biomarker; Neonatal Sepsis; Diagnostic Accuracy.*

Introduction

Neonatal bacterial meningitis is a devastating central nervous system infection carrying substantial global morbidity and mortality.

Affecting approximately 0.1 to 0.4 per 1,000 live births globally, the incidence rises significantly among preterm infants and low birth weight neonates. Despite advances in neonatal intensive care and antimicrobial therapy, approximately 10% of affected neonates succumb to the infection, and 20% to 50% of survivors experience permanent neurological sequelae, including cognitive impairment, motor abnormalities, developmental delay, and sensory deficits. Early initiation of appropriate broad-spectrum antimicrobial therapy is vital to optimize clinical outcomes; however, establishing a definitive diagnosis relies on successful cerebrospinal fluid (CSF) examination and positive cultures. Clinical presentation is notoriously non-specific, frequently mimicking neonatal sepsis, and traditional CSF parameters (such as leukocyte counts, glucose, and protein) exhibit considerable overlap between infected and non-infected infants, especially in preterm neonates with inherently permeable blood-brain barriers. Furthermore, traumatic lumbar punctures—occurring in up to 40% of procedures—frequently confound cytological and biochemical interpretations. These diagnostic limitations necessitate the exploration of novel biochemical markers capable of providing rapid, reliable diagnostic precision. Procalcitonin (PCT), a calcitonin precursor protein, has emerged as a robust systemic marker of bacterial infection. While serum PCT has been widely investigated, the diagnostic utility of CSF procalcitonin specifically within the neonatal population remains an area requiring further elucidation. This study was undertaken to evaluate the diagnostic efficacy of CSF PCT and establish a reliable clinical cut-off value for neonatal meningitis.

Methodology

This hospital-based observational study was conducted in the Neonatal Intensive Care Unit (NICU) of SDM College of Medical Sciences and Hospital, Dharwad, over a one-year study period from November 2019 to October 2020. Ethical approval was obtained from the institutional ethical committee, and written informed consent was secured from the parents or legal guardians of all participating neonates prior to enrollment.

Inclusion Criteria: Neonates admitted to the NICU presenting with clinical features suggestive of sepsis or meningitis (such as lethargy, poor feeding, apnea, temperature instability, seizures, respiratory distress, or jaundice) who underwent a complete septic workup including lumbar puncture were included.

Exclusion Criteria: Neonates older than 28 days of age, infants with concurrent focal infections outside the central nervous system, neonates with extremely low birth weight (<1000g), or those with recent neurosurgical interventions were excluded from the analysis.

Sample Collection and Laboratory Analysis: Under strict aseptic precautions, 1 mL of CSF was collected via lumbar puncture into sterile containers. Samples were immediately transported to the laboratory for cytological examination (total and differential leukocyte counts), biochemical estimation (glucose and protein), Gram staining, and microbiological culture. CSF Procalcitonin levels were measured quantitatively using a chemiluminescence immunoassay method on the ADVIA Centaur CP system.

Results

A total of 43 neonates fulfilling the inclusion and exclusion criteria were evaluated. Based on standardized diagnostic criteria (National Neonatology Forum, India), subjects were categorized into a meningitis group (n = 22) and a non-meningitis control group (n = 21). The cohort comprised 15 male infants (34.88%) and

28 female infants (65.12%). Gestational age distribution showed 11 early preterms (25.58%), 8 late preterms (18.60%), and 24 term infants (55.81%).

Comparative analysis of CSF biochemical and cytological parameters between the meningitis and non-meningitis groups is summarized in Table 1 below

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CSF Parameter	Meningitis (Mean ± SD)	Non-Meningitis (Mean ± SD)	t-value	p-value
CSF Protein (mg/dL)	131.00 ± 65.89	93.07 ± 39.71	2.27	0.0284 *
CSF Sugar (mg/dL)	48.85 ± 33.32	50.62 ± 14.48	-0.22	0.8235
CSF Procalcitonin (ng/mL)	0.48 ± 0.37	0.08 ± 0.20	3.41	0.0015 *
CSF Total Leukocyte Count (cells/μL)	20.59 ± 33.36	3.71 ± 2.33	2.31	0.0259 *

As detailed in Table 1, CSF Procalcitonin levels were markedly elevated in neonates with bacterial meningitis (mean 0.48 ng/mL) compared to the non-meningitis control group (mean 0.08 ng/mL), demonstrating a highly statistically significant difference ($p = 0.0015$). Similarly, CSF protein concentrations and total leukocyte counts were significantly elevated in the meningitis cohort ($p < 0.05$). Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate the diagnostic accuracy of CSF parameters, summarized in Table 2.

Test Variable	AUC	Std. Error	p-value	95% CI Lower	95% CI Upper
CSF Protein	0.695	0.082	0.029*	0.534	0.856
CSF Sugar	0.369	0.087	0.142	0.198	0.540
CSF Procalcitonin (PCT)	0.789	0.074	0.001*	0.645	0.933
CSF Total Leukocyte Count	0.866	0.059	0.0001*	0.751	0.981

Discussion

Neonatal bacterial meningitis is a life-threatening medical emergency where prompt antimicrobial therapy dictates survival and neurological outcome. Because blood and CSF cultures require 24 to 72 hours for definitive identification—and yield negative results in 15% to 30% of culture-proven or clinically compatible cases—clinicians heavily rely on cytological and biochemical parameters. However, physiological immaturity in preterm neonates, elevated baseline protein permeability, and traumatic lumbar punctures frequently confound traditional interpretations. Our findings demonstrate that Cerebrospinal Fluid Procalcitonin serves as a robust and reliable diagnostic biomarker with an area under the ROC curve of 0.789 ($p = 0.001$). At an optimal cut-off value of 0.13 ng/mL, CSF PCT exhibited high sensitivity (86.36%), making it an excellent screening tool to rule out bacterial meningitis when clinical suspicion is high but conventional parameters are ambiguous.

These observations align closely with recent literature. Bandiya et al. reported an AUC of 0.867 for CSF procalcitonin at a cut-off of 0.12 ng/mL, highlighting its diagnostic reliability. Similarly, Reshi et al. demonstrated high diagnostic accuracy with an AUC of 0.926 at a cut-off of 0.33 ng/mL, noting that CSF PCT provides critical diagnostic performance comparable to traditional leukocyte and

neutrophil counts. The minor variations in optimal cut-off values across studies are attributable to differences in mean birth weight, gestational age distribution, and timing of lumbar puncture relative to antimicrobial administration. Notably, in clinical scenarios complicated by traumatic lumbar punctures—where red blood cell contamination artificially elevates CSF leukocyte counts and protein levels—CSF procalcitonin concentrations remain largely unaltered by peripheral blood contamination, offering a distinct clinical advantage.

Conclusion

In conclusion, Cerebrospinal Fluid Procalcitonin measurement exhibits high diagnostic efficacy in identifying neonatal bacterial meningitis, performing comparably to traditional CSF parameters. While routine clean CSF taps may not always require adjunctive biomarkers, quantitative CSF Procalcitonin measurement is highly beneficial in diagnostic dilemmas, particularly in cases with traumatic lumbar punctures, prior antibiotic exposure, or inconclusive cytological and biochemical findings. Integrating CSF Procalcitonin into standard neonatal septic workups enhances diagnostic confidence and supports timely therapeutic decision-making in neonatal intensive care.

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