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Original Research Article

Aetiology, Clinical Profile and Short-Term Outcomes of Acute Bacterial Meningitis Among Children in Eastern India: A Prospective Observational Study

Sonali Pal[1], Sunil Kumar Agarwalla[2]

[1]Junior Resident, Department of Pediatrics, SCB MCH, Cuttack and SVPPGIP, Cuttack, India
[2]Professor, Department of Pediatrics, SCB MCH, Cuttack and SVPPGIP, Cuttack, India

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Corresponding Author: Sunil Kumar Agarwalla
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Abstract:

Background: Acute bacterial meningitis (ABM) remains a major cause of childhood mortality and neurological morbidity in low- and middle-income countries, despite the introduction of conjugate vaccines. Data describing the post-vaccine aetiology, clinical profile, and outcomes of paediatric ABM using contemporary diagnostic methods are limited from Eastern India. We aimed to characterise the aetiological spectrum, clinical features, and short-term outcomes of childhood ABM in a tertiary care setting.

Methods: We conducted a prospective, observational study at two tertiary care hospitals in Cuttack, Odisha, India, between March 2024 and March 2026. Children aged 2 months to 14 years with clinically suspected and cerebrospinal fluid–confirmed acute bacterial meningitis were enrolled. Cerebrospinal fluid samples underwent cytological, biochemical, microbiological, and molecular analyses, including PCR/CBNAAT where indicated. Demographic data, immunisation status, clinical presentation, and outcomes were recorded. Children were followed up for one month after discharge. Outcomes included aetiological confirmation, in-hospital mortality, and short-term neurological sequelae.

Findings: Among 9,020 paediatric admissions, 131 children (1·45%) were diagnosed with acute bacterial meningitis. Infants aged 2 months to 1 year accounted for 53·4% of cases, and 56·5% of children presented more than 48 hours after symptom onset. An aetiological diagnosis was established in 86 (65·6%) children. Molecular diagnostics identified pathogens in 59·5% of cases, compared with 31·3% by culture. Streptococcus pneumoniae was the most common pathogen (35·1%), followed by Haemophilus influenzae (13·7%) and Neisseria meningitidis (6·9%). Only 41·2% of children had received pneumococcal conjugate vaccine.

In-hospital mortality was 11·5%, increasing to 13·0% at one month. Neurological sequelae were observed in 19·1% of survivors.

Keywords: Acute bacterial meningitis, Paediatric infections, Pneumococcal disease, Molecular diagnosis, Neurological outcomes.

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Introduction

One of the most deadly infectious diseases impacting children globally is acute bacterial meningitis (ABM), which disproportionately affects low- and middle-income countries (LMICs). Bacterial meningitis continues to cause significant juvenile mortality and long-term neurological damage, especially in newborns and young children, despite significant advancements in antimicrobial therapy and the worldwide distribution of conjugate vaccinations. According to recent estimates from the Global Burden of Disease study, meningitis causes over 230,000 deaths each year, with the bulk of deaths and disability-adjusted life years lost occurring in children under five. [1]

Over the past 20 years, conjugate vaccines against Neisseria meningitidis, Streptococcus pneumoniae, and Haemophilus influenzae type b (Hib) have significantly altered the epidemiology of children ABM. In high-income settings, Hib meningitis has been virtually eliminated, and pneumococcal meningitis has declined substantially. [2] However, these gains have been uneven across regions. In many parts of South and Southeast Asia, incomplete vaccine coverage, delayed health-care access, and limited diagnostic capacity have attenuated the full impact of immunisation programmes. [3] As a result, vaccine-preventable pathogens—particularly S pneumoniae—continue to dominate paediatric

meningitis cases, often with unacceptably high case fatality rates.

India carries a substantial share of the regional meningitis burden. Although Hib-containing vaccines were introduced into the Universal Immunisation Programme in 2011 and pneumococcal conjugate vaccine (PCV) has been progressively rolled out since 2017, national and subnational data suggest persistent heterogeneity in coverage and disease outcomes. [4] Hospital-based studies from different regions of India continue to report high mortality (10–20%) and frequent neurological sequelae among survivors, particularly among infants and partially immunised children. [5] However, most available data are limited by small sample sizes, reliance on conventional microbiology alone, and inadequate post-vaccine-era pathogen characterisation.

For the purpose of directing empirical treatment, tracking the effects of vaccines, and influencing public health policy, accurate identification of the aetiological agents of ABM is essential. Gram staining and conventional cerebrospinal fluid (CSF) culture have low sensitivity, particularly in children who receive antibiotics prior to hospitalization—a frequent occurrence in LMIC settings. Polymerase chain reaction (PCR)-based assays are one type of molecular diagnostic tool that significantly improves pathogen identification and has shown a higher burden of pneumococcal disease than previously thought. However, molecular diagnostics are still underutilized in ordinary clinical practice in a large portion of India, which leads to incomplete surveillance and an underestimation of the true illness burden.

Eastern India, including the state of Odisha, represents a setting where childhood ABM remains a major clinical challenge. The region is characterised by mixed urban–rural populations, variable immunisation uptake, and delayed presentation to tertiary care facilities. Yet, contemporary data describing the post-vaccine epidemiology, clinical profile, diagnostic yield using molecular methods, and short-term outcomes of paediatric ABM from this region are scarce.

We sought to characterize the aetiological range, clinical presentation, and short-term outcomes of acute bacterial meningitis in children hospitalized to a tertiary care hospital in Eastern India between the ages of two months and fourteen years. This study aims to produce regionally relevant evidence to guide clinical management, vaccination strategies, and meningitis control efforts in South and Southeast Asia by combining traditional CSF analysis with molecular diagnostic techniques and methodically evaluating immunization status and early neurological outcomes.

Methodology

Design and environment of the study: At the Sardar Vallabhbhai Patel Post Graduate Institute of Paediatrics (SVPPGIP) and S.C.B. Medical College and Hospital in Cuttack, Odisha, India, we carried out a prospective, observational hospital-based study. These establishments are tertiary referral centers that primarily serve Eastern Indian rural and urban populations. The research was conducted from March 2024 to March 2026.

Study population: Children with a clinical diagnosis of acute bacterial meningitis who were admitted to the pediatric wards or pediatric intensive care unit between the ages of two months and fourteen years were eligible for inclusion. In addition to cerebrospinal fluid (CSF) results suggestive of bacterial infection, compatible clinical characteristics (fever, seizures, altered sensorium, or meningeal symptoms) were used to identify acute bacterial meningitis. Children who had serious comorbid illnesses that could independently affect clinical outcomes or whose CSF results were unclear or suggestive of viral or tubercular meningitis were excluded.

Sample size and enrolment: Based on the anticipated hospital prevalence of acute bacterial meningitis and the permitted precision, a minimum sample size of 131 children was determined. After obtaining written informed consent from parents or legal guardians, all eligible children who met the inclusion criteria during the study period were enrolled via purposeful consecutive sampling.

Data collection: Demographic characteristics, socioeconomic status, immunisation history, presenting symptoms, duration of illness prior to admission, and findings of general and neurological examination were recorded using a structured case record form. Disease severity was assessed using the Glasgow Coma Scale (GCS) at presentation.

Immunisation status was classified as fully immunised, partially immunised, or unimmunised based on age-appropriate vaccination records, with specific documentation of receipt of pneumococcal conjugate vaccine and pentavalent vaccine.

Cerebrospinal fluid analysis and microbiological investigations: Lumbar puncture was performed under strict aseptic precautions unless contraindicated. CSF samples were analysed for cytology (total and differential leukocyte count), biochemistry (glucose and protein), Gram stain, and bacterial culture with antimicrobial susceptibility testing.

To improve aetiological yield, molecular diagnostic testing was performed where indicated, including cartridge-based nucleic acid amplification test (CBNAAT) and real-time polymerase chain reaction

(RT-PCR). Aetiological confirmation was defined as identification of a bacterial pathogen by at least one microbiological or molecular method.

Clinical management and follow-up: All children received empirical antimicrobial therapy and supportive care according to institutional and national treatment protocols. Treatment details, complications, duration of hospital stay, and in-hospital outcomes were documented.

Children were followed up for one month after discharge, either through outpatient visits or telephonic contact. Outcomes assessed included survival, complete recovery, and presence of short-term neurological sequelae such as seizures, focal motor deficits, or altered sensorium.

Outcomes: The primary outcome was the distribution of etiological agents causing acute bacterial meningitis. Secondary outcomes included frequency of acute bacterial meningitis among paediatric admissions, in-hospital mortality, complications, and short-term neurological outcomes at one-month follow-up.

Analysis of statistics: The Statistical Package for the Social Sciences (SPSS), version 29, was used to analyze the data after it was input into Microsoft Excel. Frequencies and percentages were used to summarize categorical variables, whereas the mean and standard deviation were used to represent continuous variables. A two-sided p value of less than 0·05 was considered statistically significant.

Ethical considerations: The Institutional Ethics Committee of S.C.B. Medical College and Hospital, Cuttack, gave its approval to the study. Before enrollment, parents or legal guardians provided written informed consent. Throughout the trial, patient anonymity was upheld.

Results

During the study period, 9,020 children were admitted, of whom 131 (1.45%) were diagnosed with acute bacterial meningitis (Table 1). Most affected children were infants aged 2 months to 1 year (53.4%), and males accounted for nearly two-thirds of cases. More than half of the children (56.5%) presented after 48 hours of symptom onset, and 18.3% had severe neurological impairment (GCS <8) at admission.

Aetiological confirmation was achieved in 86 (65.6%) children (Table 2). Molecular diagnostics substantially improved pathogen detection, with PCR/CBNAAT identifying pathogens in 59.5% of cases compared with 31.3% by culture. Streptococcus pneumoniae was the most frequently identified pathogen (35.1%), followed by Haemophilus influenzae (13.7%) and Neisseria meningitidis (6.9%). No pathogen was identified in 34.4% of children despite clinical and laboratory features consistent with bacterial meningitis.

Age-specific analysis showed that S pneumoniae predominated across all age groups, while H influenzae and gram-negative bacilli were more common in infants. N meningitidis was identified mainly among children older than 5 years (Table 3).

Fever was the most common presenting symptom (95.4%), followed by seizures (44.3%) and altered sensorium (37.4%) (Table 4). Meningeal signs were present in 65.6% of cases. Cerebrospinal fluid analysis showed marked pleocytosis with neutrophilic predominance, elevated protein concentrations, and reduced glucose levels, consistent with bacterial meningitis.

Only 47.3% of children were fully immunised for age, and pneumococcal vaccine coverage was 41.2% (Table 5). Overall, in-hospital mortality was 11.5%, increasing to 13.0% at one-month follow-up. Neurological sequelae were documented in 19.1% of survivors.

Tables

Table 1: Demographic characteristics, clinical presentation, and disease severity among children diagnosed with acute bacterial meningitis.

Characteristic	Value (n = 131)
Total paediatric admissions during study period	9,020
Acute bacterial meningitis cases, n (%)	131 (1·45)
Age group, n (%)	
• 2 months–1 year	70 (53·4)
• 1–5 years	45 (34·4)
• >5–14 years	16 (12·2)
Male sex, n (%)	83 (63·4)
Lower socioeconomic status, n (%)	78 (59·5)
Duration of symptoms >48 h before admission, n (%)	74 (56·5)
Glasgow Coma Scale <8 at presentation, n (%)	24 (18·3)

Table 2: Diagnostic yield of cerebrospinal fluid investigations and distribution of identified bacterial pathogens.

Category	Variable	n (%)
Diagnostic modality	Gram stain	52 (39·7)
	CSF culture	41 (31·3)
	PCR/CBNAAT	78 (59·5)
	Any method (overall confirmation)	86 (65·6)
Aetiological agents	Streptococcus pneumoniae	46 (35·1)
	Haemophilus influenzae	18 (13·7)
	Neisseria meningitidis	9 (6·9)
	Gram-negative bacilli	10 (7·6)
	Other bacteria	3 (2·3)
	No pathogen identified	45 (34·4)

Table 3: Distribution of bacterial pathogens causing acute bacterial meningitis by age group.

Pathogen	2 months–1 year	1–5 years	>5–14 years
Streptococcus pneumoniae	22	18	6
Haemophilus influenzae	13	4	1
Neisseria meningitidis	1	3	5
Gram-negative bacilli	9	1	0

Table 4: Clinical presentation and cerebrospinal fluid findings among children with acute bacterial meningitis.

Variable	Value
Fever, n (%)	125 (95·4)
Seizures, n (%)	58 (44·3)
Altered sensorium, n (%)	49 (37·4)
Meningeal signs, n (%)	86 (65·6)
CSF leukocyte count (cells/mm³), mean ± SD	820 ± 510
Neutrophils in CSF (%), mean ± SD	78 ± 15
CSF protein (mg/dL), mean ± SD	165 ± 70
CSF glucose (mg/dL), mean ± SD	32 ± 18

Table 5: Immunisation status, mortality, and short-term neurological outcomes among children with acute bacterial meningitis

Variable	n (%)
Fully immunised for age	62 (47·3)
Received pneumococcal conjugate vaccine	54 (41·2)
In-hospital mortality	15 (11·5)
Mortality at one-month follow-up	17 (13·0)
Neurological sequelae at one month	25 (19·1)

Figures

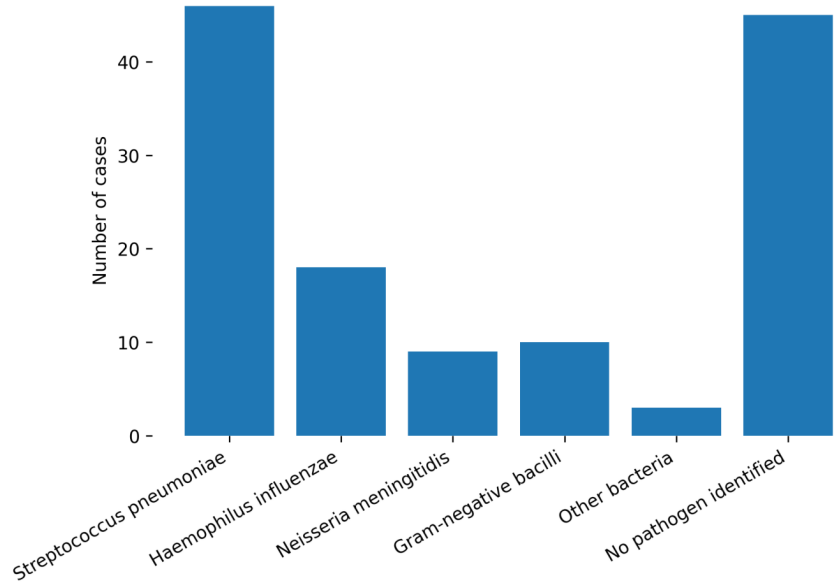

Figure 1: Distribution of bacterial pathogens causing acute bacterial meningitis

Discussion

In this prospective study from Eastern India, acute bacterial meningitis (ABM) accounted for 1·45% of paediatric hospital admissions and was associated with substantial mortality and neurological morbidity. Infants were disproportionately affected, and more than half of children presented after 48 hours of symptom onset, highlighting delayed access to care. Despite the introduction of conjugate vaccines into the national immunisation programme, Streptococcus pneumoniae remained the leading cause of ABM across all age groups. Molecular diagnostics substantially increased pathogen detection, yet one-third of cases remained aetiologically unconfirmed. Mortality exceeded 10%, and nearly one in five survivors had short-term neurological sequelae, underscoring the persistent severity of ABM in the post-vaccine era. [8-10]

The predominance of S pneumoniae in our cohort is consistent with post–Hib-vaccine-era data from India and other low- and middle-income countries (LMICs), where pneumococcus has emerged as the principal cause of childhood ABM. [11-13] Several Indian hospital-based studies have reported pneumococcal meningitis in 30–60% of confirmed cases, with mortality ranging from 10% to 20%, comparable to our findings. [12-14] Similar trends have been documented across South and Southeast Asia, indicating that the benefits of pneumococcal conjugate vaccines have been unevenly realised. [15,16]

The diagnostic yield achieved using PCR-based methods in this study aligns with growing evidence that molecular diagnostics substantially outperform conventional culture, particularly in settings where pre-hospital antibiotic exposure is common. Studies from India and other LMICs have demonstrated up to a two-fold increase in pathogen detection with PCR-based assays. [17-19] Nevertheless, the persistently high proportion of culture- and PCR-negative cases observed both in our study and others highlights ongoing diagnostic gaps, likely related to prior antibiotic use, limited pathogen panels, and unrecognised non-bacterial causes. [20]

The mortality and burden of neurological sequelae observed in this study are consistent with reports from comparable resource-limited settings but remain substantially higher than those reported in high-income countries, where case fatality rates are typically below 5%. [21-23] This disparity reflects differences in timeliness of presentation, access to intensive care, vaccination coverage, and availability of structured follow-up services. [24]

Policy implications: The findings of this study have important implications for meningitis control strategies in India and the wider Southeast Asian region. First, the continued dominance of pneumococcal meningitis despite vaccine availability underscores the urgent need to strengthen pneumococcal conjugate vaccine coverage through improved programme implementation, catch-up strategies, and targeted outreach to underserved populations. [25,26] Second, delayed presentation in more than half of affected children highlights critical health-system barriers, including limited caregiver awareness and referral delays, which must be addressed through community education and strengthened primary care networks. [27]

Third, the substantial improvement in aetiological confirmation with molecular diagnostics supports their integration into standard diagnostic algorithms

at tertiary care centres. Enhanced diagnostic capacity is essential not only for individual patient management but also for monitoring vaccine impact, guiding empirical therapy, and informing antimicrobial stewardship. [18,19,28] Finally, the high prevalence of neurological sequelae underscores the need for structured post-discharge follow-up, including neurodevelopmental and audiological assessment, a key priority emphasised in the WHO roadmap to defeat meningitis by 2030. [2,29]

This study's prospective design, methodical data collection, integration of molecular diagnostics with traditional microbiology, and short-term follow-up to evaluate neurological outcomes are among its strong points. The study fills a significant evidentiary vacuum by offering current post-vaccine-era data from an underrepresented area of India. [1,13] But there are a few restrictions to be aware of. The study's limited applicability to community settings may result from its solitary tertiary care facility. Multivariable studies of mortality and sequelae factors were limited by the sample size. Detailed serotyping and antibiotic resistance profiling were not carried out, and molecular testing was not consistently applied to every case. Lastly, evaluation of long-term neurodevelopmental outcomes—which are known to significantly contribute to the overall burden of disease—was not possible due to the one-month follow-up period. [22,23,29]

Limitations: There are several restrictions on this study. Initially, the study was carried out at a single tertiary care facility, which would restrict its applicability in primary or community settings. Second, molecular diagnostic testing and detailed bacterial serotyping were not uniformly available for all cases, restricting more granular assessment of vaccine impact. Finally, follow-up was limited to one month, precluding evaluation of long-term neurodevelopmental and audiological outcomes.

Conclusion

In Eastern India, acute bacterial meningitis continues to be a leading cause of neurological illness and juvenile death, especially in babies and inadequately immunized children. Streptococcus pneumoniae still predominates despite the availability of conjugate vaccinations, which is indicative of gaps in pneumococcal immunization coverage and delayed presentation to care. Incorporating molecular diagnostics into standard clinical practice at tertiary centers is recommended since it significantly enhances aetiological confirmation. Reducing avoidable deaths and long-term impairment from childhood bacterial meningitis in the area requires bolstering immunization programs, encouraging early detection and referral, and guaranteeing organized post-discharge follow-up

Declaration of interests: All authors declare no competing interests.

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Ethical approval: The study was approved by the Institutional Ethics Committee of S.C.B. Medical College and Hospital, Cuttack. Written informed consent was obtained from the parents or legal guardians of all participating children prior to enrolment.

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