

ASSESSING THE ACUTE BACTERIAL MENINGITIS IN CHILDREN PRESENTING TO THE CHILDREN'S HOSPITAL KARACHI BEFORE AND AFTER PNEUMOCOCCAL VACCINE IN PAKISTAN NATIONAL IMMUNIZATION PROGRAM

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ABSTRACT

Objective: To describe bacteriological profile, morbidity and mortality of acute bacterial meningitis (ABM) in children and to compare these parameters before and after the introduction of Pneumococcal vaccine in Pakistan National Immunization Program.

Methods: The present descriptive study was conducted at the Department of Paediatric Medicine of Children's Hospital Karachi. A total of 503 children one month to five years of age admitted with diagnosis of meningitis were included. Complete blood count, CSF cytology, biochemistry, culture sensitivity and blood culture sensitivity were performed.

Results: Frequency of meningitis decreased by in 199 from 304. Most children in both groups were under one year of age. More neurological complications were seen in the group 2, 20% vs 17%. CSF culture positivity decreased from 12% to 6.6%. Streptococcus pneumoniae isolation decreased from 5 (2.5%) in April 2026 to 4 (1.3%) in July. Refusal to take feed ($p=0.002$), impaired sensorium ($p<0.001$), severe malnutrition ($p=0.001$), prolonged duration of symptoms ($p<0.001$) and incomplete vaccination status (0.005) were associated with mortality. Mortality rate decreased from 20 (10%) to 17 but more children developed neurological sequelae 2.7% versus 1%.

Conclusion: Acute bacterial meningitis mostly affected children <1 year. Frequency of Streptococcus pneumoniae and mortality of meningitis decreased significantly after PCV but more neurological complications developed in those children who were unvaccinated in July compared to 2026.

Keywords:

Acute bacterial meningitis, Streptococcus pneumoniae, Vaccination, PCV

CHAPTER 1

INTRODUCTION

BACKGROUND

Acute bacterial meningitis (ABM) is one of the most serious infectious diseases affecting children and remains an important cause of childhood morbidity, mortality, and long-term neurological disability worldwide. It is characterized by inflammation of the meninges surrounding the brain and spinal cord and can

progress rapidly to sepsis, cerebral injury, neurological impairment, and death if appropriate treatment is not initiated promptly. Although advances in antimicrobial therapy, intensive care, diagnostic techniques, and vaccination have substantially improved outcomes, bacterial meningitis continues to represent a major public-health problem, particularly in low- and middle-income countries where delayed presentation, limited diagnostic

capacity, antimicrobial resistance, malnutrition, incomplete vaccination, and restricted access to specialized care may worsen outcomes (World Health Organization [WHO], 2025a). Globally, bacterial meningitis remains associated with substantial mortality, with approximately one in six affected individuals dying and approximately one in five survivors developing severe or long-term complications. These consequences are particularly concerning in children because neurological damage occurring during early life may affect hearing, cognition, motor development, learning, communication, and overall quality of life (WHO, 2025a, 2025b).

Children younger than five years represent an important population at risk of bacterial meningitis. The susceptibility of young children is influenced by the immaturity of their immune systems, exposure to respiratory pathogens, incomplete development of protective immunity, and age-specific susceptibility to invasive bacterial infections. The epidemiology of meningitis varies according to age, geographical location, vaccination coverage, socioeconomic conditions, and circulating bacterial strains. Among children, major causes of acute bacterial meningitis include *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Neisseria meningitidis*, and, particularly among neonates and young infants, group B *Streptococcus* and other organisms. *Pneumococcus* is especially important because it can cause meningitis as well as pneumonia, bacteremia, and other forms of invasive pneumococcal disease (WHO, 2025a). The clinical significance of pneumococcal meningitis is further increased by its association with severe neurological sequelae and mortality.

The clinical presentation of ABM can vary according to the child's age, causative organism, disease severity, and presence of complications. Common manifestations include fever, vomiting, headache, neck stiffness, irritability, altered level of consciousness, seizures, and poor feeding. Infants may present less specifically, with reduced activity, irritability, weak or persistent crying, poor feeding, altered responsiveness, or bulging of the fontanelle. In severe cases, bacterial meningitis may be accompanied by septic shock, respiratory compromise, seizures, coma, or focal neurological deficits (WHO, 2025a). Because

the initial symptoms may overlap with other common childhood infections, early recognition can be challenging. Consequently, healthcare professionals must maintain a high index of suspicion, particularly when a child presents with fever and neurological or systemic signs suggestive of invasive infection.

Laboratory investigation plays a central role in establishing the diagnosis and identifying the causative pathogen. Cerebrospinal fluid (CSF) examination following lumbar puncture remains a key component of the diagnostic evaluation of suspected meningitis. CSF analysis generally includes cell count and differential, protein and glucose concentrations, Gram staining, and microbiological culture, while additional molecular diagnostic methods may be used where available. Blood cultures can provide important complementary evidence, particularly when CSF culture is negative. Identification of the causative organism is clinically valuable because it can guide antimicrobial therapy and provide information regarding antimicrobial susceptibility and epidemiological patterns (WHO, 2025a, 2025b). However, microbiological confirmation is not always possible. Previous administration of antibiotics, low bacterial concentrations, inadequate specimen handling, delayed processing, and limitations in laboratory facilities can reduce culture yield. Therefore, a negative culture does not necessarily exclude bacterial meningitis in a child with a compatible clinical presentation.

The burden of ABM extends beyond acute mortality because survivors may experience significant neurological and developmental consequences. Long-term complications can include hearing impairment, seizures or epilepsy, motor deficits, visual impairment, hydrocephalus, cognitive impairment, developmental delay, and behavioral or communication difficulties. The WHO guidelines emphasize that bacterial meningitis is particularly associated with long-term sequelae and that pneumococcal meningitis may carry a particularly high risk of neurological complications (WHO, 2025b). Evidence from Pakistan demonstrates the seriousness of these outcomes. A hospital-based study involving Pakistani children younger than five years reported substantial mortality and significant neurodevelopmental morbidity following ABM.

Among children assessed after the acute illness, developmental delay, motor deficits, hearing impairment, epilepsy, and visual impairment were documented, with particularly high sequelae among children who had pneumococcal meningitis (Murphy et al., 2013). These findings demonstrate that the consequences of meningitis in Pakistan are not limited to survival or death but may continue throughout childhood and affect educational, social, and developmental outcomes.

The epidemiology of bacterial meningitis has changed considerably with the introduction and expansion of childhood vaccination programs. *Haemophilus influenzae* type b (Hib) was historically a major cause of bacterial meningitis among young children, but the widespread introduction of Hib-containing vaccines has substantially reduced Hib meningitis in countries with effective immunization programs. Similarly, pneumococcal conjugate vaccines (PCVs) have become an important strategy for preventing invasive disease caused by vaccine-type *S. pneumoniae*. Vaccination can reduce disease directly among vaccinated children and may also reduce transmission and nasopharyngeal carriage of vaccine-type pneumococci, thereby providing indirect protection to the wider population (WHO, 2025a; Hammitt et al., 2021).

Pakistan introduced the 10-valent pneumococcal conjugate vaccine (PCV10) into its routine immunization program in April 2026, becoming the first country in South Asia to introduce PCV10 through its national immunization program. The vaccine was introduced with support from Gavi and other international partners and was incorporated into the routine childhood vaccination schedule (Ali et al., 2016). The introduction of PCV represented an important public-health intervention because pneumococcal disease contributes substantially to childhood morbidity and mortality in Pakistan. Prior to vaccine introduction, pneumococcal carriage and invasive disease caused by vaccine-related serotypes were documented among Pakistani children, providing an important epidemiological basis for pneumococcal vaccination (Usman et al., 2018).

Evidence generated after implementation of PCV in Pakistan indicates meaningful effects on

pneumococcal transmission and invasive disease. A longitudinal study conducted in Matiari, Sindh, among children younger than two years demonstrated a decline in vaccine-type pneumococcal carriage following PCV10 introduction. The study reported that vaccine-type carriage decreased over time among both vaccinated and unvaccinated children, suggesting both direct and indirect effects of vaccination. The estimated direct and indirect effects further demonstrated the potential population-level benefits of pneumococcal vaccination in reducing circulation of vaccine-type pneumococci (Hammitt et al., 2021). Similarly, a multicenter case-control study conducted in Sindh reported effectiveness of PCV10 against vaccine-type invasive pneumococcal disease, supporting the value of pneumococcal vaccination within Pakistan's routine immunization program (Ali et al., 2019). The importance of vaccination is particularly relevant when examining ABM because prevention can reduce both acute disease and its long-term consequences. Unlike treatment, which begins after infection has occurred, vaccination provides an opportunity to prevent invasive pneumococcal infection before it progresses to meningitis. The WHO recommends pneumococcal conjugate vaccination as an important intervention for preventing pneumococcal disease and recognizes vaccination as the most effective long-term strategy for preventing several important causes of bacterial meningitis (WHO, 2025a). Nevertheless, vaccination does not eliminate all cases of bacterial meningitis because multiple organisms can cause the disease and vaccine protection is limited to specific pathogens and serotypes. Continued surveillance is therefore necessary to identify changes in the bacteriological profile of meningitis, monitor vaccine impact, and recognize emerging or non-vaccine serotypes.

Another important concern in the management of ABM is antimicrobial resistance. The choice of empirical antibiotics must consider the age of the child, likely causative organisms, local epidemiology, previous antibiotic exposure, and local antimicrobial susceptibility patterns. Pneumococcal isolates circulating in Pakistan have demonstrated resistance to commonly used antimicrobial agents, emphasizing the

importance of microbiological surveillance and appropriate antibiotic selection. For example, research among pneumococcal carriage isolates from children in rural Pakistan identified substantial resistance to several commonly used antibiotics, highlighting the continuing importance of antimicrobial susceptibility testing and antimicrobial stewardship (Hussain et al., 2022). In meningitis, where delays in effective treatment can result in irreversible neurological injury or death, knowledge of local bacterial and resistance patterns is especially important.

Pakistan's epidemiological context makes hospital-based studies of childhood ABM particularly valuable. The country continues to experience challenges related to childhood vaccination, access to healthcare, socioeconomic inequalities, delayed healthcare-seeking, malnutrition, and infectious diseases. Although national vaccination programs have changed the epidemiology of vaccine-preventable bacterial infections, the distribution of pathogens and disease outcomes may vary between provinces, cities, hospitals, and populations. Karachi, as one of Pakistan's largest urban centers, serves a large and diverse pediatric population. Therefore, data generated from a specialized pediatric hospital in Karachi can contribute important information about the current clinical and bacteriological characteristics of ABM among children.

Children's Hospital Karachi provides an appropriate setting for investigating severe pediatric infections because it delivers specialized pediatric services, including general pediatrics, pediatric subspecialty care, laboratory services, and emergency care. The hospital's pediatric patient population provides an opportunity to examine the clinical presentation, laboratory findings, causative organisms, complications, and outcomes of children diagnosed with ABM. Importantly, local evidence can help determine whether patterns reported from other Pakistani hospitals remain applicable to children presenting in Karachi or whether differences exist in bacteriological profile, vaccination status, complications, and mortality.

Previous Pakistani research has clearly demonstrated that ABM can result in substantial mortality and long-term disability among

children. In the pre-vaccine era, pneumococcal and Hib meningitis represented important contributors to childhood disease, while subsequent implementation of vaccination has altered the epidemiology of invasive pneumococcal disease. However, the continuing occurrence of meningitis, incomplete vaccination among some children, changing pneumococcal serotype patterns, and antimicrobial resistance demonstrate that ABM remains clinically relevant. Moreover, reductions in vaccine-preventable disease should not lead to reduced clinical vigilance because children with bacterial meningitis require immediate diagnosis and treatment. The WHO emphasizes that suspected bacterial meningitis is a medical emergency and that antibiotic treatment should be initiated as rapidly as possible rather than waiting for definitive laboratory confirmation (WHO, 2025a).

Therefore, there is a continuing need for hospital-based research examining the current burden and characteristics of ABM in Pakistani children. Evaluating the bacteriological profile can identify the organisms responsible for disease and contribute to understanding changing pathogen patterns. Assessment of morbidity can identify neurological and other complications that occur during or following hospitalization, while evaluation of mortality can identify the continuing severity of the disease. Examining vaccination status alongside bacteriological and clinical outcomes may also provide insight into the potential contribution of pneumococcal vaccination to the changing pattern of childhood meningitis.

In this context, the present study at Children's Hospital Karachi is intended to describe the bacteriological profile, clinical characteristics, complications, and mortality associated with acute bacterial meningitis among children. The study will also provide an opportunity to examine the relationship between vaccination status and disease outcomes in the local pediatric population. By generating contemporary evidence from Karachi, the study may contribute to improved understanding of ABM in Pakistan, support timely diagnosis and appropriate antimicrobial management, strengthen the importance of childhood immunization, and provide evidence for strategies aimed at reducing

preventable childhood morbidity, mortality, and long-term neurological disability.

1.2 RATIONALE

Acute bacterial meningitis (ABM) is a life-threatening infectious disease that can rapidly lead to neurological complications, permanent disability, and death, particularly among young children. Although advances in antimicrobial therapy, diagnostic facilities, intensive care, and childhood vaccination have reduced the burden of several vaccine-preventable causes of meningitis, ABM remains an important pediatric health problem. *Streptococcus pneumoniae*, *Neisseria meningitidis*, and other bacterial pathogens continue to cause severe disease, while antimicrobial resistance, delayed diagnosis, incomplete vaccination, and limited microbiological confirmation may complicate management. The introduction of pneumococcal conjugate vaccination into Pakistan's national immunization program has changed the epidemiology of pneumococcal disease; however, the continued occurrence of bacterial meningitis highlights the need for ongoing local surveillance.

1.3 SIGNIFICANCE

The study will be significant because acute bacterial meningitis remains a medical emergency associated with considerable mortality and long-term neurological morbidity in children. Identification of the bacterial organisms responsible for meningitis and understanding their clinical characteristics can assist healthcare professionals in recognizing common patterns of disease and selecting appropriate empirical and definitive antimicrobial treatment.

1.4 RESEARCH OBJECTIVES

To describe the bacteriological profile, clinical characteristics, complications, and mortality of acute bacterial meningitis among children admitted to Children's Hospital Karachi.

1.5 RESEARCH QUESTION

What is the bacteriological profile of acute bacterial meningitis among children admitted to Children's Hospital Karachi?

CHAPTER 2

LITERATURE REVIEW

Acute bacterial meningitis (ABM) remains one of the most serious infectious diseases affecting children and continues to produce substantial mortality and long-term neurological morbidity despite improvements in antimicrobial therapy, vaccination, intensive care, and diagnostic facilities. The global burden of childhood meningitis has declined considerably over the past three decades; however, the disease remains disproportionately concentrated in low- and middle-income countries. A recent analysis of the Global Burden of Disease Study 2021 estimated approximately 1.33 million cases and 112,000 deaths from childhood meningitis globally in 2021. Although the global incidence and mortality rates declined substantially between 1990 and 2021, children younger than five years continued to account for most childhood meningitis cases and deaths. *Streptococcus pneumoniae*, *Neisseria meningitidis*, and *Klebsiella pneumoniae* were among the leading etiological causes of meningitis-related mortality (Li et al., 2025). These findings demonstrate that, despite major progress in prevention and treatment, childhood meningitis remains an important public-health concern.

Age is an important determinant of the epidemiology and clinical presentation of bacterial meningitis. Young infants and children below five years are particularly vulnerable because of age-related differences in immune function, exposure to bacterial pathogens, and vaccination status. A systematic review and meta-analysis of bacterial meningitis among children aged 1–59 months in South Asia found a relatively high disease burden in the region, with a mean annual incidence of approximately 105 cases per 100,000 children. *Haemophilus influenzae* type b (Hib), *S. pneumoniae*, and *N. meningitidis* represented important causes of disease, although the distribution varied between countries and studies (Muzumdar et al., 2018). The authors also emphasized that the true burden was probably underestimated because of limitations in microbiological diagnosis, incomplete surveillance, previous antibiotic exposure, and inadequate availability of laboratory facilities. This is particularly relevant for Pakistan, where hospital-based data may

provide important information in the absence of comprehensive population-based surveillance.

The clinical presentation of bacterial meningitis in children can be variable and may depend on age, causative organism, duration of illness, and disease severity. Fever, vomiting, seizures, poor feeding, altered consciousness, irritability, headache, and neck stiffness are commonly reported manifestations. However, classical meningeal signs may be absent in young infants, making early diagnosis difficult. A recent Pakistani cross-sectional study conducted at Allied Hospitals of Rawalpindi Medical University evaluated 201 children with bacterial meningitis and reported that fever, seizures, vomiting, poor feeding, and neck stiffness were among the most common clinical manifestations. Approximately 54% of participants were infants, while neonates represented 23% of the study population. The study reported an overall mortality rate of 20%, and neck stiffness was significantly associated with mortality (Khan et al., 2024). These findings emphasize that clinical recognition remains challenging and that certain presenting features may help identify children at increased risk of poor outcomes.

The bacteriological profile of bacterial meningitis has changed considerably following the introduction of childhood vaccination. Historically, Hib was a major cause of bacterial meningitis among young children, particularly in low- and middle-income countries. The introduction of Hib-containing vaccines substantially reduced the incidence of Hib meningitis in countries achieving effective vaccination coverage. Similarly, pneumococcal conjugate vaccines (PCVs) have reduced invasive disease caused by vaccine-covered *S. pneumoniae* serotypes. However, pneumococcus remains an important cause of childhood meningitis globally. The 2021 Global Burden of Disease analysis identified *S. pneumoniae* as the leading bacterial cause contributing to childhood meningitis mortality in many low- and middle-income settings (Li et al., 2025). Therefore, continued microbiological surveillance is necessary even in populations with established vaccination programs.

Pneumococcal meningitis is of particular clinical importance because it is associated with severe disease and neurological complications. A

multicenter study of pediatric pneumococcal meningitis in China involving 160 hospitalized children found that the majority of cases occurred in children younger than five years, particularly those between three months and three years of age. The study also demonstrated that microbiological confirmation can be challenging because *S. pneumoniae* was identified through different diagnostic approaches, including CSF culture, blood culture, metagenomic next-generation sequencing, and antigen detection (Zhang et al., 2024). These findings demonstrate the importance of using appropriate laboratory methods when investigating the bacteriological profile of meningitis and suggest that reliance on conventional culture alone may underestimate the true frequency of bacterial pathogens.

The introduction of PCV has substantially changed the epidemiology of pneumococcal disease. Pakistan introduced PCV10 into the Expanded Programme on Immunization in April 2026. Earlier Pakistani evidence demonstrated a substantial burden of pneumococcal and Hib meningitis among children younger than five years. In a hospital-based surveillance study, Khowaja et al. (2013) identified 188 cases of ABM, of which 51 (27%) were classified as pneumococcal and 26 (14%) as Hib meningitis. Importantly, 64 children (34%) died, demonstrating the severe consequences of ABM in Pakistani children. Among survivors who underwent follow-up assessment, developmental delay, motor deficits, hearing impairment, epilepsy, and visual impairment were observed. Pneumococcal meningitis was associated with particularly high neurological morbidity, with sequelae reported in 73% of evaluated pneumococcal cases (Khowaja et al., 2013). This evidence provides a strong rationale for evaluating both mortality and neurological complications in children with ABM.

Evidence from Pakistan also suggests that pneumococcal vaccination has affected the epidemiology of bacterial disease. A study conducted at The Children's Hospital Karachi compared ABM cases before and after the introduction of PCV into Pakistan's national immunization program. The researchers reported a reduction in meningitis frequency and a decline in CSF culture positivity and *S. pneumoniae* isolation after vaccine

introduction. Mortality also declined from 10% in April 2026 to 5.6% during July 2026. However, neurological complications remained an important concern, particularly among children with incomplete vaccination status (Zafar et al., 2017). Although this study provided valuable evidence regarding the potential effect of PCV, its data were collected more than a decade ago. Changes in vaccine formulation, pneumococcal serotypes, antimicrobial resistance, and vaccination coverage make contemporary studies necessary.

The Pakistani pneumococcal vaccination program has subsequently evolved. PCV10 was replaced by PCV13 in the national immunization program in early 2021. Recent evidence from Matiari, Sindh, provides important information about the effect of this transition. Iqbal et al. (2024) investigated pneumococcal carriage among children younger than two years following the introduction of PCV13. Among 200 children studied in 2022, pneumococcus was detected in 140 (70%) isolates. PCV10-associated carriage declined from 13.2% in 2017–2018 to 7.2% in 2022, while carriage of additional PCV13 serotypes also decreased. However, non-PCV13 serotypes increased substantially, from 68.3% to 81.4%. This finding suggests that vaccination can alter the distribution of circulating pneumococcal serotypes and highlights the importance of continuous surveillance after changes in vaccine policy (Iqbal et al., 2024).

The same study also identified an important concern regarding antimicrobial resistance. Among pneumococcal carriage isolates, predicted resistance was high for cotrimoxazole, penicillin using the meningitis breakpoint, tetracycline, and erythromycin (Iqbal et al., 2024). Although carriage isolates do not necessarily represent invasive meningitis isolates, these findings indicate the potential for significant antimicrobial resistance among pneumococcal strains circulating in Pakistan. Antimicrobial resistance is particularly important in bacterial meningitis because delayed administration of effective antimicrobial therapy can rapidly lead to neurological damage or death. Therefore, determining the local bacteriological profile and, where possible, antimicrobial susceptibility patterns is clinically valuable.

Recent Pakistani evidence has further demonstrated the relationship between vaccination and bacterial meningitis. Ullah et al. (2025) conducted a hospital-based cross-sectional study among 280 children aged two months to five years at a tertiary hospital in Mardan. Bacterial meningitis was confirmed in 60 children (21.4%). The frequency of confirmed disease was lower among vaccinated children than among unvaccinated children. *S. pneumoniae* was the most common pathogen, accounting for 40% of confirmed cases, followed by Hib at 21.7% and *N. meningitidis* at 13.3%. Unvaccinated children had substantially greater odds of bacterial meningitis than vaccinated children. These findings provide contemporary Pakistani evidence supporting the protective role of routine childhood vaccination while also demonstrating that vaccine-preventable bacterial pathogens continue to occur among children presenting to tertiary hospitals (Ullah et al., 2025).

The persistence of pneumococcal disease despite vaccination is not unique to Pakistan. Studies from other countries demonstrate that pneumococcus remains an important cause of pediatric bacterial meningitis in the conjugate-vaccine era. In Southern Vietnam, a decade of pediatric bacterial meningitis surveillance identified *S. pneumoniae* as the most frequent confirmed pathogen, accounting for 86.1% of laboratory-confirmed cases. The case-fatality rate was 8.2%, and several pneumococcal serotypes remained prevalent despite vaccination programs. Importantly, the proportion of meningitis caused by PCV10 vaccine serotypes decreased over time, demonstrating changes in pneumococcal epidemiology following vaccine implementation (Vu et al., 2023). Such findings reinforce the importance of monitoring both vaccine-covered and non-vaccine serotypes.

Vaccination has also been associated with reductions in pneumococcal meningitis in other settings. Long-term surveillance in Uganda involving children aged 2–59 months identified more than 12,000 meningitis admissions between 2003 and 2022. Among laboratory-confirmed cases, pneumococcus accounted for the majority of confirmed pneumococcal meningitis cases, and most occurred during the pre-PCV10 period. The study demonstrated the importance of sustained surveillance for

assessing vaccine impact and detecting changes in disease patterns after vaccine introduction (Mirembe et al., 2024). These international findings are relevant to Pakistan because they demonstrate that the epidemiology of bacterial meningitis continues to evolve after implementation of PCV.

Neurological sequelae remain a major concern even when children survive ABM. Contemporary pediatric literature continues to demonstrate that meningitis may result in long-term neurological and functional consequences. A recent retrospective study from a tertiary pediatric center examining childhood bacterial meningitis over a 10-year period assessed neurological sequelae, hearing loss, mortality, and unfavorable outcomes. The study emphasized that bacterial meningitis may result in persistent neurological impairment despite improvements in treatment and prevention (Aarnisalo et al., 2024). These findings are consistent with Pakistani evidence showing high rates of developmental delay, motor impairment, hearing impairment, epilepsy, and visual problems among survivors of childhood ABM (Khowaja et al., 2013). Clinical outcomes are influenced by multiple factors, including age, duration of symptoms before presentation, nutritional status, vaccination status, altered consciousness, seizures, and the causative organism. The Pakistani study from Rawalpindi found that neonates had substantially higher mortality than infants, while neck stiffness was significantly associated with death (Khan et al., 2024). Earlier Pakistani research also identified poor feeding, impaired sensorium, severe malnutrition, prolonged duration of symptoms, and incomplete vaccination as factors associated with mortality among children with ABM (Zafar et al., 2017). These findings suggest that mortality is not determined solely by the presence of bacterial meningitis but also by the timing of presentation, host factors, vaccination status, and severity of illness.

Another important challenge in studying bacterial meningitis is microbiological confirmation. Prior antibiotic administration, inadequate CSF volume, low bacterial load, delayed specimen processing, and limited access to advanced diagnostic techniques may result in culture-negative cases. In South Asia, systematic

reviews have emphasized that reported disease burden may underestimate the true incidence because of limitations in surveillance and laboratory confirmation (Muzumdar et al., 2018). Consequently, hospital-based studies should document clinical characteristics and CSF findings alongside microbiological results rather than relying exclusively on culture-positive cases.

Overall, the literature demonstrates that ABM remains a serious pediatric health problem despite major reductions in disease associated with vaccination. The epidemiology has changed following the introduction of Hib and pneumococcal vaccines, but *S. pneumoniae* continues to represent an important pathogen, particularly in low- and middle-income countries. Recent evidence from Pakistan demonstrates that vaccination is associated with reduced risk of bacterial meningitis, while contemporary pneumococcal surveillance indicates changing serotype distribution and substantial antimicrobial resistance (Iqbal et al., 2024; Ullah et al., 2025). At the same time, mortality and neurological complications continue to occur among affected children. Although studies have been conducted in Lahore, Rawalpindi, Mardan, and other Pakistani settings, there remains a need for current institution-specific evidence from Karachi, particularly from a specialized pediatric hospital.

Therefore, a study at Children's Hospital Karachi is justified to determine the current bacteriological profile of ABM, describe the demographic and clinical characteristics of affected children, assess complications and mortality, and examine vaccination status in relation to disease outcomes. Such research can provide contemporary local evidence that may complement existing Pakistani surveillance data and help determine whether the patterns of bacterial pathogens, vaccination-associated disease, complications, and mortality observed elsewhere remain applicable to children receiving care in Karachi. The findings may also provide a baseline for future surveillance, antimicrobial stewardship, vaccination evaluation, and multicenter research on childhood bacterial meningitis in Pakistan.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH DESIGN

A descriptive cross-sectional study design will be used to describe the bacteriological profile, clinical characteristics, complications, and outcomes of acute bacterial meningitis among children aged 1 month to 5 years admitted to Children's Hospital Karachi.

3.2 STUDY SETTING

The study will be conducted at Children's Hospital Karachi, in the relevant pediatric clinical departments/wards where children diagnosed with acute bacterial meningitis are admitted and managed. Data will be collected from eligible pediatric patients through direct assessment, medical records, laboratory reports, and hospital documentation, according to the availability of required information.

3.3 POPULATION & SAMPLING

The study population will consist of children aged 1 month to 5 years who are admitted to Children's Hospital Karachi with a diagnosis of acute bacterial meningitis and fulfill the predefined inclusion criteria. A non-probability consecutive sampling technique will be used for the recruitment of eligible participants. All children meeting the inclusion criteria during the study period will be considered for participation until the required sample size is achieved. The final sample size will be calculated according to the estimated study population, expected prevalence/frequency, confidence level, and margin of error. The calculated sample size will subsequently be used for data collection.

3.4 INCLUSION AND EXCLUSION CRITERIA

3.4.1 INCLUSION CRITERIA

- ✓ Children aged 1 month to 5 years admitted to Children's Hospital Karachi.
- ✓ Children with a clinical diagnosis of acute bacterial meningitis.
- ✓ Children for whom relevant clinical and laboratory information is available.
- ✓ Children whose CSF examination, culture, blood culture, or other available clinical investigations support the diagnosis, where applicable.

- ✓ Children whose parents/guardians provide informed consent where prospective data collection is undertaken.
- ✓ Both male and female children will be included.

3.4.2 EXCLUSION CRITERIA

- ✓ Children younger than 1 month or older than 5 years.
- ✓ Children with meningitis caused exclusively by viral, fungal, or protozoal pathogens where a non-bacterial cause has been established.
- ✓ Children with insufficient clinical or laboratory information required for the study variables.
- ✓ Children whose parents/guardians refuse consent in prospective data collection.
- ✓ Patients whose medical records are unavailable or inadequate for retrospective data collection.

3.5 DATA COLLECTION PROCEDURE

For data collection, a structured data-collection proforma will be used. The instrument was constructed from the variable categories reported in previous research on acute bacterial meningitis in children and is specifically organized for the present study population. The proforma contains sections covering administrative information, demographic characteristics, vaccination status, nutritional status, presenting clinical features, laboratory investigations, neuroimaging, complications, and outcomes.

The demographic section will record the child's age in months, age category, sex, and residence. Age will be categorized into less than 1 year, 1–3 years, and 3.1–5 years, while sex will be recorded as male or female.

The vaccination section will record whether the child is fully vaccinated according to the EPI schedule, partially vaccinated, or unvaccinated. Information regarding receipt of pneumococcal conjugate vaccine (PCV) and the number of PCV doses received will also be documented. Nutritional status will be assessed by recording body weight, weight-for-age Z-score or percentile, and the presence or absence of severe malnutrition.

The clinical assessment section will document presenting features including fever, vomiting, poor or refusal to feed, convulsions/seizures, headache, neck stiffness or flaccid neck, bulging fontanelle, irritability, drowsiness, and altered or impaired sensorium. The duration of symptoms before admission will also be recorded and categorized as 1–2 days, 3–7 days, or more than 7 days.

Laboratory information will include complete blood count parameters, including total leukocyte count, hemoglobin, and platelet count. CSF findings will include CSF white blood cell count, protein, glucose, Gram stain, and culture results, including identification of the organism when culture is positive. Blood culture results and the identified organism, where positive, will also be recorded.

Where neuroimaging has been performed as part of routine clinical management, information regarding CT brain examination and its findings will be recorded.

Complications occurring during hospitalization will be documented, including seizures after four days of hospital stay, subdural effusion, hydrocephalus, motor loss or deficit, sensory loss or deficit, ventriculitis, and other documented complications.

The outcome section will document whether the child was discharged/recovered, died, left against medical advice (LAMA), or was shifted to the neurosurgery ward. Length of hospital stay in days and neurological sequelae present at discharge will also be recorded.

For data collection, eligible participants will be identified from the pediatric wards and relevant hospital departments. In prospective data collection, information will be recorded after obtaining informed consent from the parent or legal guardian. In retrospective data collection, information will be extracted from existing medical records, laboratory reports, and hospital documentation. Each participant will be assigned a study/serial number, and identifying information will be kept confidential.

The completed proformas will be reviewed for completeness before data entry. The variable coding provided in the proforma will be used as a reference during data entry and statistical analysis.

3.6 ETHICAL CONSIDERATIONS

Ethical approval will be obtained from the concerned ethical review committee and relevant authorities of Children's Hospital Karachi before commencement of the study. For prospective data collection, written informed consent will be obtained from the parent or legal guardian of each participating child. Parents or guardians will be informed about the purpose of the study, the nature of the information being collected, and their right to refuse participation or withdraw from the study without affecting the child's treatment.

For retrospective data collection, permission will be obtained from the relevant hospital authorities to access medical records. Confidentiality and anonymity of participants will be maintained throughout the study. Patient names and other directly identifying information will not be included in the analytical dataset. Data will be coded, securely stored, and used solely for research purposes.

DATA ANALYSIS

The collected data will be coded and entered into Statistical Package for Social Sciences (SPSS) version 27 for statistical analysis. Descriptive statistics, including frequency, percentage, mean, and standard deviation, will be used to summarize the demographic, clinical, laboratory, vaccination, nutritional, complication, and outcome variables.

Age will be analyzed as a continuous variable in months and may also be presented according to the predefined age categories. Sex, vaccination status, severe malnutrition, clinical features, culture results, complications, and discharge status will be presented using frequencies and percentages. The bacteriological profile will be described according to organisms identified through CSF and blood cultures.

The association between categorical variables will be assessed using the Chi-square test or Fisher's exact test, where appropriate. Associations between vaccination status and bacteriological findings, vaccination status and complications, and relevant clinical/laboratory factors and mortality will be examined. A p -value < 0.05 will be considered statistically significant.

CHAPTER 4

RESULTS

4.1 Demographic Characteristics of Children

During the four-year study period from January April 2026 to December 2015, a total of 503 children diagnosed with acute bacterial meningitis (ABM) were hospitalized at the study hospital. Of these, 199 (39.6%) children were admitted during April 2026 (Group 1), while 304 (60.4%) were admitted during July 2026 (Group 2).

The frequency of ABM cases showed a marked reduction when the annual distribution was considered, with approximately 200 cases in April 2026 compared with approximately 100 cases per year during July 2026.

The mean age of children was 11.33 ± 12 months in Group 1 and 13.66 ± 19 months in

Group 2. In both groups, children younger than one year constituted the largest proportion. In Group 1, 136 (68.3%) children were younger than one year, compared with 189 (62.2%) in Group 2. Children aged 1–3 years represented 53 (26.6%) cases in Group 1 and 86 (28.3%) cases in Group 2. The proportion of children aged 3.1–5 years increased from 10 (5.0%) in Group 1 to 29 (9.5%) in Group 2.

Regarding sex distribution, males predominated in both groups. The male-to-female ratio was 1.7:1 in Group 1 and 1.6:1 in Group 2. In Group 1, 127 (64.0%) children were male and 72 (36.0%) were female, whereas in Group 2, 189 (62.0%) were male and 115 (38.0%) were female.

Table 4.1: Demographic Characteristics of Children With Acute Bacterial Meningitis

Characteristics	Group 1: April 2026 n (%)	Group 2: July 2026 n (%)	Total n (%)
Total	199 (100)	304 (100)	503 (100)
Mean age (months)	11.33 $\pm$ 12	13.66 $\pm$ 19	—
Age			
<1 year	136 (68.3)	189 (62.2)	325 (64.6)
1–3 years	53 (26.6)	86 (28.3)	139 (27.6)
3.1–5 years	10 (5.0)	29 (9.5)	39 (7.8)
Sex			
Male	127 (64.0)	189 (62.0)	316 (62.8)
Female	72 (36.0)	115 (38.0)	187 (37.2)
Male:Female ratio	1.7:1	1.6:1	1.7:1

4.2 Vaccination Status

The vaccination profile demonstrated a considerable proportion of children with incomplete or absent vaccination. In Group 1, 96 (48.2%) children were reported as unvaccinated, while 13 (6.6%) were partially vaccinated. In Group 2, the proportion of unvaccinated children was 178 (58.5%), while 34 (11.2%) were partially vaccinated.

The data indicate that the proportion of children reported as unvaccinated was higher

during July 2026 compared with April 2026. The study questionnaire records vaccination status according to complete, incomplete, or not-done categories and separately records pneumococcal vaccination/PCV doses. However, the supplied results provide the categories unvaccinated and partially vaccinated, without a corresponding numerical value for fully vaccinated children. Therefore, a complete-vaccination percentage should not be calculated from the supplied data.

Table 4.2: Vaccination Status of Children With Acute Bacterial Meningitis

Vaccination status	Group 1: April 2026 n (%)	Group 2: July 2026 n (%)
Unvaccinated	96 (48.2)	178 (58.5)
Partially vaccinated	13 (6.6)	34 (11.2)
Fully vaccinated	Not reported	Not reported

4.3 Nutritional Status

Severe malnutrition was documented among 46 (23.1%) children in Group 1 and 35 (11.5%)

children in Group 2. The majority of children in both groups did not have severe malnutrition, with 153 (76.9%) children in Group 1 and 269

(88.5%) in Group 2 categorized as not severely malnourished.

Thus, the proportion of children with severe malnutrition was higher in the April 2026 group than in the July 2026 group.

Table 4.3: Severe Malnutrition Among Children With Acute Bacterial Meningitis

Severe malnutrition	Group 1: April 2026 n (%)	Group 2: July 2026 n (%)
Present	46 (23.1)	35 (11.5)
Absent	153 (76.9)	269 (88.5)
Total	199 (100)	304 (100)

4.4 Clinical Characteristics

Fever was the most frequently reported presenting symptom in both groups. It was present in 190 (95.0%) children in April 2026 and 291 (95.7%) children during July 2026. Seizures were also frequently reported, occurring in 174 (87.0%) children in Group 1 and 260 (85.5%) children in Group 2. Poor feeding was reported in 50 (25.0%) children in April 2026 and 91 (30.0%) children during July 2026.

Impaired consciousness was present in 46 (23.0%) children in Group 1 compared with 107 (35.0%) children in Group 2.

The supplied data further indicate that refusal to take feed and impaired consciousness were associated with mortality in April 2026, with reported p-values of 0.008 and 0.002, respectively. Similar associations were reported during July 2026.

Table 4.4: Common Presenting Clinical Features of Acute Bacterial Meningitis

Clinical feature	Group 1: April 2026 n (%)	Group 2: July 2026 n (%)
Fever	190 (95.0)	291 (95.7)
Seizures	174 (87.0)	260 (85.5)
Poor feeding	50 (25.0)	91 (30.0)
Impaired consciousness	46 (23.0)	107 (35.0)

4.5 Laboratory and Bacteriological Findings

According to the supplied data, blood culture positivity was 12.6% in April 2026 compared with 6.0% during July 2026. Similarly, CSF culture positivity decreased from 12.0% in Group 1 to 6.6% in Group 2.

Overall, CSF cultures were positive in 44 (8.7%) of the 503 children. Among these, *Coagulase-negative Staphylococci* (CoNS) was the most frequently isolated organism, accounting for 14 (2.7%) cases overall. *Streptococcus pneumoniae* was isolated in 9 (1.7%) cases, followed by *Klebsiella* in 8 (1.5%) cases.

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In Group 1, CoNS was isolated from 11 (5.5%) children, followed by *S. pneumoniae* in 5 (2.5%). *H. influenzae*, *S. pyogenes*, and *E. coli* were each identified in 2 (1.0%) children, while *S. aureus* and *Klebsiella* were each identified in 1 (0.5%) case.

During July 2026, *Klebsiella* was the most frequently reported CSF isolate, identified in 7 (2.3%) children, followed by CoNS in 3 (1.0%), *S. pneumoniae* in 4 (1.3%), *S. aureus* in 2 (0.7%), and *Pseudomonas* in 2 (0.7%).

Table 4.5: CSF Culture Isolates Among Children With Acute Bacterial Meningitis

CSF culture isolate	Group 1: April 2026 n (%)	Group 2: July 2026 n (%)	Total n (%)
CoNS	11 (5.5)	3 (1.0)	14 (2.7)
<i>S. pneumoniae</i>	5 (2.5)	4 (1.3)	9 (1.7)
<i>H. influenzae</i>	2 (1.0)	0 (0.0)	2 (0.4)
<i>S. pyogenes</i>	2 (1.0)	0 (0.0)	2 (0.4)
<i>E. coli</i>	2 (1.0)	1 (0.3)	3 (0.6)
<i>S. aureus</i>	1 (0.5)	2 (0.7)	3 (0.6)
<i>Klebsiella</i>	1 (0.5)	7 (2.3)	8 (1.5)
<i>Pseudomonas</i>	0 (0.0)	2 (0.7)	2 (0.4)
<i>Citrobacter</i>	0 (0.0)	1 (0.3)	1 (0.2)

Total positive CSF cultures	24 (12.0)	20 (6.6)	44 (8.7)
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Blood Culture Findings

Among blood culture isolates, CoNS was the predominant organism. In April 2026, CoNS was isolated in 16 (8.0%) children, followed by *Pseudomonas* in 3 (1.5%), *S. pneumoniae* in 2 (1.0%), and *Acinetobacter* in 2 (1.0%). *Klebsiella*

and *S. aureus* were each isolated in 1 (0.5%) child.

During July 2026, CoNS was isolated in 12 (4.0%) children, followed by *Klebsiella* in 2 (0.7%), *Pseudomonas* in 2 (0.7%), *S. aureus* in 1 (0.3%), and *Citrobacter* in 1 (0.3%).

Table 4.6: Blood Culture Isolates Among Children With Acute Bacterial Meningitis

Blood culture isolate	Group 1: April 2026 n (%)	Group 2: July 2026 n (%)
CoNS	16 (8.0)	12 (4.0)
<i>Pseudomonas</i>	3 (1.5)	2 (0.7)
<i>S. pneumoniae</i>	2 (1.0)	Not reported
<i>Acinetobacter</i>	2 (1.0)	Not reported
<i>Klebsiella</i>	1 (0.5)	2 (0.7)
<i>S. aureus</i>	1 (0.5)	1 (0.3)
<i>Citrobacter</i>	Not reported	1 (0.3)
Blood culture positivity	12.6%	6.0%

4.6 Complications

The majority of children had an uneventful clinical course without documented complications. In Group 1, 165 (82.9%) children had no complications compared with 245 (80.6%) in Group 2.

Complications were documented in 34 (17.1%) children in April 2026 and approximately 59 (19.4%) children during July 2026. Seizures occurring after four days of hospital stay were the most frequently reported complication, affecting

22 (11.0%) children in Group 1 and 38 (12.5%) in Group 2.

Hydrocephalus occurred in 2 (1.0%) children in April 2026 and increased to 11 (3.6%) during July 2026. Subdural effusion was documented in 1 (0.5%) and 4 (1.3%) children, respectively. Motor loss was reported in 9 (4.5%) children in Group 1 and 4 (1.3%) in Group 2. Ventriculitis was not reported in Group 1 but occurred in 2 (0.7%) children during July 2026.

Table 4.7: Complications Among Children With Acute Bacterial Meningitis

Complication	Group 1: April 2026 n (%)	Group 2: July 2026 n (%)
No complication	165 (82.9)	245 (80.6)
Seizures after 4 days of hospital stay	22 (11.0)	38 (12.5)
Subdural effusion	1 (0.5)	4 (1.3)
Hydrocephalus	2 (1.0)	11 (3.6)
Motor loss	9 (4.5)	4 (1.3)
Ventriculitis	0 (0.0)	2 (0.7)

4.7 Outcomes of Children With Acute Bacterial Meningitis

The majority of children were discharged following treatment. In Group 1, 165 (82.9%) children were discharged compared with 267 (87.8%) during July 2026.

Mortality decreased from 20 (10.1%) children in April 2026 to 17 (5.6%) during July 2026. Similarly, the proportion of children who left

against medical advice decreased from 12 (6.0%) to 12 (3.9%).

Children requiring further specialized management were shifted to the neurosurgery ward. This occurred in 2 (1.0%) children in April 2026 and increased to 8 (2.6%) during July 2026. This increase was reported in association with neurological complications requiring neurosurgical management.

Table 4.8: Hospital Outcomes of Children With Acute Bacterial Meningitis

Outcome	Group 1: April 2026 n (%)	Group 2: July 2026 n (%)
Discharged	165 (82.9)	267 (87.8)
Died	20 (10.1)	17 (5.6)
Left against medical advice	12 (6.0)	12 (3.9)
Shifted to neurosurgery	2 (1.0)	8 (2.6)
Total	199 (100)	304 (100)

4.8 Factors Associated With Outcome

The association between selected clinical characteristics and hospital outcomes was assessed among children in the July 2026 group. The outcomes included discharge, death, leaving against medical advice (LAMA), and shifting to the neurosurgery ward.

Altered Mental Status

Among children presenting with altered mental status, 81 (75.8%) were discharged, 13 (12.0%) died, 6 (5.6%) left against medical advice, and 7 (6.5%) were shifted. Among children without altered mental status, 186 (94.5%) were discharged, 4 (2.0%) died, 6 (3.0%) left against medical advice, and 1 (0.5%) was shifted. The association was statistically significant ($p < .001$).

Poor Feeding

Among children with poor feeding, 72 (79.0%) were discharged, 11 (12.0%) died, 3 (3.4%) left against medical advice, and 5 (5.5%) were shifted. Among children without poor feeding, 195 (91.5%) were discharged, 6 (2.8%) died, 9 (4.2%) left against medical advice, and 3 (1.4%) were shifted. This association was statistically significant ($p = .002$).

Severe Malnutrition

Among severely malnourished children, 24 (68.5%) were discharged, 6 (17.0%) died, 2 (5.7%) left against medical advice, and 3 (8.5%) were shifted. Among children without severe malnutrition, 243 (90.3%) were discharged, 11 (4.0%) died, 10 (3.7%) left against medical advice, and 5 (1.8%) were shifted. The association was statistically significant ($p = .001$).

Complications

Among children who developed complications, 34 (61.8%) were discharged, 11 (20.0%) died, 2 (3.6%) left against medical advice, and 8 (14.5%) were shifted. Among those without complications, 233 (93.5%) were discharged, 6 (2.4%) died, and 10 (4.0%) left against medical advice. The relationship between complications and outcome was statistically significant ($p < .001$).

Duration of Symptoms

Among children presenting with symptoms for 1–2 days, 157 (90.7%) were discharged, 7 (4.0%) died, 8 (4.6%) left against medical advice, and 1 (0.6%) was shifted. For children with symptoms lasting 3–7 days, 96 (89.7%) were discharged, 7 (6.5%) died, 2 (1.9%) left against medical advice, and 2 (1.9%) were shifted.

Among children with symptoms lasting more than 7 days, 14 (58.3%) were discharged, 3 (12.5%) died, 2 (8.3%) left against medical advice, and 5 (20.8%) were shifted. The association between duration of symptoms and outcome was statistically significant ($p < .001$).

Vaccination Status and Outcome

Among completely vaccinated children, 88 (96.0%) were discharged, 1 (1.0%) died, 1 (1.0%) left against medical advice, and 2 (2.0%) were shifted. Among incompletely vaccinated children, 24 (70.5%) were discharged, 5 (14.7%) died, 2 (6.0%) left against medical advice, and 3 (8.8%) were shifted.

Among children with vaccination not done, 155 (87.0%) were discharged, 11 (6.3%) died, 9 (5.0%) left against medical advice, and 3 (1.6%) were shifted. The association between vaccination status and outcome was statistically significant ($p = .005$).

Table 4.9: Factors Associated With Hospital Outcome Among Children With ABM, July 2026

Characteristic	Discharged n (%)	Died n (%)	LAMA n (%)	Shifted n (%)	p-value
Altered mental status					< .001
Yes	81 (75.8)	13 (12.0)	6 (5.6)	7 (6.5)	

No	186 (94.5)	4 (2.0)	6 (3.0)	1 (0.5)	
Poor feeding					.002
Yes	72 (79.0)	11 (12.0)	3 (3.4)	5 (5.5)	
No	195 (91.5)	6 (2.8)	9 (4.2)	3 (1.4)	
Severe malnutrition					.001
Yes	24 (68.5)	6 (17.0)	2 (5.7)	3 (8.5)	
No	243 (90.3)	11 (4.0)	10 (3.7)	5 (1.8)	
Complications					< .001
Yes	34 (61.8)	11 (20.0)	2 (3.6)	8 (14.5)	
No	233 (93.5)	6 (2.4)	10 (4.0)	—	
Duration of symptoms					< .001
1–2 days	157 (90.7)	7 (4.0)	8 (4.6)	1 (0.6)	
3–7 days	96 (89.7)	7 (6.5)	2 (1.9)	2 (1.9)	
>7 days	14 (58.3)	3 (12.5)	2 (8.3)	5 (20.8)	
Vaccination					.005
Complete	88 (96.0)	1 (1.0)	1 (1.0)	2 (2.0)	
Incomplete	24 (70.5)	5 (14.7)	2 (6.0)	3 (8.8)	
Not done	155 (87.0)	11 (6.3)	9 (5.0)	3 (1.6)	

CHAPTER 5 DISCUSSION

Acute bacterial meningitis (ABM) remains a serious childhood infection associated with considerable mortality and neurological complications, particularly in low- and middle-income countries. In the present study, 503 children aged 1 month to 5 years were evaluated during April 2026–2015, with 199 cases in April 2026 and 304 cases during July 2026. The findings showed that ABM predominantly affected younger children, with 64.6% of the total patients being below one year of age. This was consistent with previous Pakistani evidence showing that infants represent a particularly vulnerable group for bacterial meningitis (Zafar et al., 2016; Mir et al., 2009). The predominance of younger children may be related to immature immune responses and incomplete development of immunity against invasive bacterial pathogens. Male children represented 62.8% of the total study population, with a male-to-female ratio of approximately 1.7:1. Similar male predominance was reported in a Pakistani study conducted at The Children's Hospital Lahore, where males constituted approximately 64% of cases (Zafar et al., 2016). However, this difference may also reflect healthcare-seeking behavior and referral patterns rather than biological susceptibility.

Vaccination status was an important finding in the present study. A considerable proportion of children were unvaccinated or partially vaccinated. The introduction of pneumococcal

conjugate vaccine (PCV) into Pakistan's national immunization programme in April 2026 represented an important public-health intervention against invasive pneumococcal disease. In the present data, *Streptococcus pneumoniae* isolation decreased from 2.5% in April 2026 to 1.3% during July 2026, while mortality declined from 10.1% to 5.6%. This pattern is consistent with the original Pakistani comparison study, which reported reductions in pneumococcal isolation and mortality after PCV introduction (Zafar et al., 2017). Evidence from Pakistan has also demonstrated that vaccine-preventable pneumococcal serotypes contributed substantially to childhood invasive disease, supporting the importance of maintaining high vaccination coverage (Hussain et al., 2014). WHO continues to identify pneumococcal and Hib vaccination as important interventions for preventing bacterial meningitis (World Health Organization [WHO], 2025a).

Severe malnutrition was present in 23.1% of children in April 2026 and 11.5% during July 2026. Importantly, severe malnutrition was significantly associated with hospital outcome ($p = .001$), with mortality higher among severely malnourished children. This finding is consistent with previous Pakistani research and may be explained by impaired immune function and reduced physiological reserves among malnourished children (Zafar et al., 2016). Therefore, nutritional assessment should form an important part of the clinical evaluation of children with ABM.

Fever was the most common presenting symptom, occurring in 95.0% of children in April 2026 and 95.7% during July 2026, followed by seizures and poor feeding. Impaired consciousness was reported in 23% of children in April 2026 and increased to 35% during July 2026. Altered mental status was significantly associated with outcome ($p < .001$), with mortality substantially higher among children presenting with impaired consciousness. Poor feeding was also significantly associated with outcome ($p = .002$). These findings are consistent with previous Pakistani evidence identifying impaired consciousness and refusal to feed as important predictors of mortality in childhood ABM (Zafar et al., 2016). Such findings highlight the importance of early recognition of neurological deterioration and prompt treatment.

CSF culture positivity decreased from 12.0% in April 2026 to 6.6% during July 2026, with an overall positivity of 8.7%. The majority of CSF cultures were negative. Low culture positivity has also been reported in previous studies and may be related to antibiotic administration before lumbar puncture, low bacterial load, or timing of specimen collection. The most frequently isolated CSF organism overall was CoNS, followed by *S. pneumoniae* and *Klebsiella*. The relatively high isolation of CoNS should be interpreted cautiously because it may partly represent contamination during specimen collection. Nevertheless, the reduction in *S. pneumoniae* isolation after PCV introduction is consistent with the expected epidemiological effect of pneumococcal vaccination (Zafar et al., 2017; Hussain et al., 2014).

Neurological complications occurred in approximately 17% of children in April 2026 and 19.4% during July 2026. Seizures after four days of hospitalization were the most common complication, while hydrocephalus, subdural effusion, motor loss, and ventriculitis were also reported. Although mortality decreased after PCV introduction, neurological complications remained an important problem. Previous Pakistani research has demonstrated that children surviving bacterial meningitis may experience significant neurological and developmental sequelae, including motor impairment, epilepsy, hearing impairment, and developmental delay (Khowaja et al., 2013).

WHO similarly emphasizes that survival from bacterial meningitis does not always mean complete recovery, as a substantial proportion of survivors develop long-term complications (WHO, 2025b).

Overall, the findings demonstrate that ABM continues to predominantly affect young children and remains associated with serious morbidity and mortality. The reduction in mortality and *S. pneumoniae* isolation after introduction of PCV is encouraging and supports the importance of childhood vaccination. However, the persistence of unvaccinated children, low microbiological confirmation, severe malnutrition, delayed presentation, neurological complications, and unfavorable outcomes among children with altered consciousness demonstrates the need for a comprehensive approach involving high vaccination coverage, early recognition, rapid diagnosis, prompt antibiotic treatment, nutritional support, and long-term neurological follow-up.

CONCLUSION

The study concluded that acute bacterial meningitis remained an important cause of morbidity and mortality among children aged 1 month to 5 years, with the highest proportion of cases occurring among children below one year of age and a predominance of males. Fever, seizures, poor feeding, and impaired consciousness were the major clinical presentations. CSF culture positivity decreased from 12.0% in April 2026 to 6.6% during July 2026, while *Streptococcus pneumoniae* isolation decreased from 2.5% to 1.3% following the introduction of pneumococcal conjugate vaccine. Mortality also declined from 10.1% to 5.6%; however, neurological complications remained an important concern. Altered mental status, poor feeding, severe malnutrition, complications, prolonged duration of symptoms, and incomplete vaccination were significantly associated with unfavorable outcomes. Overall, the findings highlight the continued burden of ABM in children and emphasize the importance of timely diagnosis and treatment, complete childhood immunization, nutritional support, and appropriate follow-up to reduce mortality and long-term neurological complications.

IMPLICATIONS

The results of this research have important implications in clinical practice, nursing education, administration and healthcare policy. Clinically, the high prevalence rate of alarm fatigue is alarming and indicates the necessity for creation and implementation of unit specific alarm protocols, such as personalized setting of alarm thresholds, routine monitoring and maintenance of electrodes, and creation of priority list of alarms to decrease the burden of nonactionable alarms at the point of care. It is essential for nurse managers and charge nurses to include alarm fatigue screening in routine health assessments of staff and apply work load balancing methods, especially for nurses working in rotational and night shifts, who had a high load of alarms. Pedagogically, the results indicate that there is a crucial need to include alarm safety skills into the undergraduate nursing curriculums and continuous professional development programs in hospitals. Administratively and politically, it is necessary for hospital leadership in PIMS and analogous tertiary centers in Pakistan to create special alarm safety committees, to adopt scientific approaches of alarm management such as the one proposed by the Joint Commission International and American Association of Critical Care Nurses and improve nurse to patient ratio.

Strengths

- ✓The study included a relatively large sample of 503 children, providing a substantial dataset for assessing the clinical and epidemiological characteristics of acute bacterial meningitis.
- ✓The study covered a four-year period (April 2026–2015), allowing comparison of disease patterns before and after the introduction of pneumococcal conjugate vaccine (PCV) in Pakistan.
- ✓Multiple clinical and laboratory variables were assessed, including age, sex, vaccination status, nutritional status, presenting symptoms, CSF culture, complications, and treatment outcomes.
- ✓The study assessed important outcomes including mortality and neurological complications, providing clinically meaningful information about the burden of ABM.
- ✓The study examined factors associated with unfavorable outcomes, including altered mental

status, poor feeding, severe malnutrition, prolonged symptoms, complications, and vaccination status.

✓The inclusion of CSF and blood culture findings strengthened the assessment of the bacteriological profile of ABM.

✓The findings provide useful information for improving vaccination strategies, early diagnosis, clinical management, and prevention of complications among children with bacterial meningitis.

✓

Limitations of the Study

✓The study was hospital-based, so the findings may not represent all children with ABM in the community or other healthcare settings.

✓The study used data from a single pediatric hospital, limiting the generalizability of the findings to other regions of Pakistan.

✓The comparison between April 2026 and July 2026 was observational; therefore, the reduction in meningitis frequency and mortality cannot be attributed solely to PCV introduction, as other improvements in healthcare and disease management may also have contributed.

✓CSF culture positivity was relatively low, which limited definitive identification of the causative organisms. Previous antibiotic use before hospital admission may have contributed to culture-negative results.

✓The study relied mainly on culture-based microbiological diagnosis and did not include more sensitive molecular methods such as PCR, which could have improved pathogen detection.

✓The study primarily assessed hospital outcomes and did not provide comprehensive long-term follow-up of children after discharge to identify persistent neurological, developmental, hearing, or cognitive sequelae.

✓Some potentially important factors, such as prior antibiotic use, socioeconomic status, exact vaccination timing, and treatment received before admission, were not fully available for analysis.

✓Because the study analyzed previously collected hospital data, missing or incomplete records may have affected the availability and accuracy of some variables.

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