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Prevalence of Hearing Loss in Diagnosed Patients with Meningitis

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ABSTRACT

Background: Meningitis remains a life-threatening condition in children and is frequently complicated by neurological sequelae, with hearing loss being the most common and clinically significant outcome. Despite global recognition of this association, there is limited regional evidence in South Asia, where systematic post-meningitis auditory screening is rarely implemented and children remain at risk of undiagnosed disability. Objective: To determine the prevalence and severity of hearing loss among children diagnosed with meningitis at a tertiary care hospital in Lahore. Methods: A cross-sectional analytical study was conducted at the Children's Hospital Lahore between September 2022 and February 2023. A purposive sample of 127 children aged 0–12 years with confirmed meningitis and documented normal pre-morbid hearing were enrolled. Audiological evaluation included otoscopy, otoacoustic emissions, pure tone audiometry, and auditory brainstem response. Data were analyzed using SPSS v24, with descriptive statistics, chi-square tests, odds ratios, 95% confidence intervals, and p-values reported. Results: Of the 127 participants, 78 (61.4%) were male and 76 (59.8%) were aged 0–3 years. Normal hearing was preserved in 48 children (37.8%). Mild hearing loss occurred in 23 (18.1%), moderate in 32 (25.2%), severe in 4 (3.1%), and profound in 20 (15.7%). The association between meningitis and hearing loss was statistically significant (p = 0.021). Conclusion: Nearly two-thirds of children developed post-meningitic hearing impairment, most commonly moderate in severity, with profound loss present in a substantial minority. Routine post-meningitis auditory screening is essential for early detection and timely rehabilitation to mitigate long-term developmental and psychosocial consequences.

Keywords
Meningitis, Hearing Loss, Sensorineural Impairment, Pediatrics, Audiology, Pakistan

INTRODUCTION

Hearing is a fundamental sensory function essential for communication, cognitive development, and social interaction, and any disruption in auditory pathways can have profound consequences in children. The human auditory system spans the external, middle, and inner ear, enabling detection of sound frequencies from 20 Hz to 20,000 Hz and their translation into meaningful neural signals (1). Impairment may range from mild to profound and can be conductive, sensorineural, or mixed in origin, often resulting in delayed speech and language acquisition, reduced educational performance, and diminished psychosocial wellbeing (2). Among the acquired causes of childhood hearing loss, meningitis represents a particularly severe risk factor, given its ability to trigger irreversible sensorineural hearing loss through cochlear invasion, inflammation, and subsequent neuronal damage (3).

Despite advances in preventive strategies, bacterial meningitis continues to impose a considerable global health burden, with nearly 1.2 million cases reported annually and childhood mortality rates approaching 30% (4). Beyond mortality, long-term complications such as hearing impairment remain highly prevalent, with reports suggesting that up to 50% of pneumococcal meningitis survivors may develop some degree of sensorineural hearing loss (5). Mechanistically, inflammatory responses within the cochlea, cytokine-mediated neurotoxicity, and ischemic injury contribute to auditory dysfunction, often bilaterally, necessitating interventions such as hearing aids or cochlear implantation to restore function (6). These outcomes highlight the need for systematic post-meningitis screening and rehabilitation strategies.

International literature demonstrates considerable variation in prevalence rates of post-meningitic hearing loss. Persson et al. reported that 60% of patients in Sweden developed hearing impairment, with pneumococcal infection and concurrent otitis media emerging as significant predictors (7). In contrast, Jatto et al. documented a 30.4% prevalence in Nigeria, while Zeeshan et al. found that 22% of Pakistani children surviving meningitis experienced measurable hearing loss (8,9). Such variability may be explained by differences in healthcare systems, diagnostic criteria, or timeliness of care, but consistently affirms meningitis as a high-risk condition for permanent auditory disability. Importantly, limited data are available from South Asia, where systematic post-meningitis hearing assessments are seldom implemented despite high disease burden (10).

From a public health perspective, failure to address hearing loss in meningitis survivors compounds the burden of childhood disability, particularly in low- and middle-income countries where access to audiological services and rehabilitative care is scarce. Early identification through routine post-discharge screening can mitigate developmental and psychosocial impacts, yet anecdotal evidence suggests this remains underutilized in

clinical practice in Pakistan. Existing gaps in regional evidence prevent the establishment of standardized guidelines for auditory follow-up, leaving many children undiagnosed and untreated at critical stages of development.

Given this context, the present study was undertaken to generate robust local evidence on the prevalence and distribution of hearing loss among children diagnosed with meningitis in a tertiary care setting in Lahore. The objective was to quantify the proportion of children affected and categorize the severity of impairment using validated audiological tools. By doing so, this study seeks to address the knowledge gap in South Asia and provide a foundation for policy development advocating for routine post-meningitis hearing assessments in pediatric populations.

Research Objective: To determine the prevalence and severity of hearing loss in children aged 0–12 years diagnosed with meningitis at a tertiary hospital in Lahore.

MATERIAL AND METHODS

This study employed a cross-sectional analytical design, chosen for its suitability in estimating prevalence and exploring associations between meningitis and hearing loss within a defined pediatric population. The research was conducted at the Children's Hospital Lahore, a large tertiary care referral center providing specialized pediatric services to a diverse catchment population. Data collection occurred over a four-month period from September 2022 and February 2023, ensuring an adequate recruitment window to achieve the calculated sample size.

Eligible participants included male and female children aged 0–12 years who had a confirmed diagnosis of meningitis, established through clinical assessment and supporting laboratory findings, and who had documented normal hearing status prior to the illness. Children with congenital hearing loss, chronic suppurative otitis media, otitis media with effusion, upper respiratory tract infection, or other comorbidities known to affect auditory function were excluded to minimize confounding. A purposive sampling approach was adopted due to the clinical nature of the recruitment setting, enabling systematic identification of eligible patients during their hospital stay or outpatient follow-up. Informed written consent was obtained from parents or guardians following detailed explanation of study aims and procedures, and assent was sought from children where age appropriate.

Data collection procedures followed a structured protocol. Each child underwent a baseline otoscopic examination to exclude external or middle ear pathology and confirm tympanic membrane integrity. Subsequent audiological assessments included otoacoustic emissions (OAE) to evaluate outer hair cell function, particularly useful for younger or non-cooperative children (11). Pure tone audiometry (PTA) was conducted where feasible to measure auditory thresholds at frequencies between 250 Hz and 8000 Hz, with hearing loss operationally defined as a threshold greater than 25 dB in accordance with international standards (12). Auditory brainstem response (ABR) testing was performed for participants unable to undergo behavioral audiometry, thereby ensuring objective estimation of auditory sensitivity across all children (13). Demographic variables such as age and sex were recorded, alongside clinical details including age at onset of meningitis. The severity of hearing loss was categorized as mild (26–40 dB), moderate (41–55 dB), moderately severe (56–70 dB), severe (71–90 dB), or profound (>90 dB).

To minimize bias and enhance validity, strict inclusion and exclusion criteria were applied to prevent misclassification of pre-existing hearing conditions. Using multiple complementary audiological tools reduced measurement error and improved diagnostic reliability. Audiologists performing the tests were blinded to the clinical details of meningitis severity to limit observer bias. The sample size was determined using a reference prevalence of 30.4% hearing loss following meningitis reported in Nigerian children, applying a 95% confidence level with $Z = 1.96$ and a margin of error of 0.08, yielding a required sample size of 127 children, which was successfully recruited.

Statistical analysis was performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). Categorical variables including gender and degree of hearing loss were summarized as frequencies and percentages, while continuous variables such as age were reported as means with standard deviations where appropriate. Prevalence estimates were accompanied by 95% confidence intervals. Comparisons across age groups and sex were tested using chi-square statistics, and associations between meningitis and hearing loss categories were expressed using odds ratios with 95% confidence intervals. A p-value <0.05 was considered statistically significant. Missing data were handled through complete case analysis, and no imputation was applied given the cross-sectional design. Subgroup analyses by age group were conducted to explore differential vulnerability patterns.

Ethical approval for the study was obtained from the Institutional Review Board of the University of Lahore. All procedures adhered to the principles of the Declaration of Helsinki, with written informed consent obtained from guardians and confidentiality maintained through de-identified data entry and secure, password-protected storage. Steps to ensure reproducibility and data integrity included standardized training of audiologists, calibration of equipment prior to each testing session, double data entry with verification to reduce transcription errors, and documentation of all protocols in detail to allow replication by other researchers.

RESULTS

A total of 127 children with meningitis were evaluated, with a clear male predominance of 61.4% (78 boys) compared to 38.6% (49 girls). The majority of participants were very young, as 76 children (59.8%) were aged 0–3 years, while 22 (17.3%) were between 10–12 years, 17 (13.4%) fell in the 7–9 year group, and only 12 (9.4%) were between 4–6 years. This distribution underscores that nearly six out of every ten cases were concentrated in the earliest developmental stage, suggesting heightened vulnerability to post-meningitic complications in infancy and early childhood. A statistically significant difference was observed in sex distribution, with boys being disproportionately affected ($p = 0.042$).

Audiological outcomes revealed that normal hearing was preserved in only 48 children, corresponding to 37.8% of the total sample (95% CI: 32.8–42.8).

Table 1. Age and sex distribution of study participants (n = 127)

Variable	Frequency (n)	Percent (%)	p-value
Age group (years)			
0–3	76	59.8	—
4–6	12	9.4	—
7–9	17	13.4	—
10–12	22	17.3	—

Sex			
Male	78	61.4	0.042*
Female	49	38.6	

*Chi-square test; $p < 0.05$ considered statistically significant.

These finding highlights that almost two-thirds of meningitis survivors experienced some degree of hearing loss. Among those affected, 23 children (18.1%, 95% CI: 13.2–22.9) exhibited mild impairment, while 32 (25.2%, 95% CI: 20.5–29.9) demonstrated moderate hearing loss, making it the single most frequent category of auditory deficit. Severe hearing loss was detected in 4 children (3.1%, 95% CI: 1.3–5.0), whereas profound impairment was present in 20 (15.7%, 95% CI: 11.1–20.3). The overall distribution of hearing loss across severity levels was statistically significant ($p = 0.021$), reinforcing meningitis as a major risk factor for post-infectious auditory disability.

Table 2. Distribution of hearing outcomes among study participants (n = 127)

Degree of Hearing Loss	Frequency (n)	Percent (%)	95% CI (%)	p-value
Normal	48	37.8	32.8 – 42.8	—
Mild	23	18.1	13.2 – 22.9	—
Moderate	32	25.2	20.5 – 29.9	—
Severe	4	3.1	1.3 – 5.0	—
Profound	20	15.7	11.1 – 20.3	0.021*

*Chi-square test for distribution of hearing loss; $p < 0.05$ considered statistically significant.

Taken together, these results indicate that nearly two out of every three children surviving meningitis were left with permanent hearing impairment, with moderate and profound categories collectively representing over 40% of all cases. The predominance of moderate deficits emphasizes the substantial clinical burden, while the presence of profound loss in one-sixth of children highlights the risk of lifelong communication challenges without early rehabilitative intervention.

DISCUSSION

The present study demonstrated that nearly two-thirds of children diagnosed with meningitis developed some degree of hearing loss, with moderate impairment being the most common outcome and profound loss present in a considerable proportion. These finding underscores meningitis as a significant contributor to childhood auditory disability in Pakistan and aligns with the global evidence base documenting the high prevalence of post-infectious hearing impairment. The predominance of moderate to profound categories highlights the destructive potential of meningitis pathology when early detection and intervention are lacking, a concern of particular importance in low- and middle-income countries where access to rehabilitative resources remains limited.

When compared with international data, the prevalence observed in this cohort corresponds closely with studies conducted in higher-resource settings. Persson et al. reported that 60% of bacterial meningitis survivors in Sweden exhibited measurable hearing loss, particularly in cases associated with pneumococcal infection and concurrent otitis media (14). Similarly, West et al. emphasized that up to half of pneumococcal meningitis cases may progress to sensorineural hearing loss through direct cochlear injury and inflammatory pathways (5). By contrast, studies from low-resource countries such as Nigeria have reported somewhat lower prevalence, with Jatto et al. documenting hearing impairment in 30.4% of children (8). In Pakistan, Zeeshan et al. identified post-meningitic hearing loss in 22% of cases, a lower figure than that found here (9). The higher prevalence in the current cohort may be explained by delayed clinical presentation, variability in diagnostic thresholds, or differences in case mix, particularly with regard to pneumococcal meningitis which is associated with the most severe sequelae (6,14).

The pathophysiological mechanisms underlying these findings are well recognized. Bacterial pathogens may access the cochlea via the cochlear aqueduct, initiating an inflammatory cascade characterized by cytokine release, oxidative stress, and vascular compromise, leading to permanent loss of inner hair cells and cochlear neurons (5,6). This explains the predominance of bilateral impairment, as symmetrical cochlear injury is typical of meningitis-associated hearing loss (6). The pattern of severity in the present study, with moderate impairment being most frequent, followed by profound loss, likely reflects variability in inflammatory response, timeliness of antimicrobial therapy, and individual host susceptibility. Such mechanistic insights emphasize the need for early audiological screening, as subtle deficits may otherwise go undetected in young children, delaying intervention at a critical stage of language and cognitive development (2).

From a clinical perspective, the implications of these findings are considerable. Children with untreated hearing impairment face significant challenges in speech acquisition, educational achievement, and psychosocial integration, particularly in settings where inclusive education and rehabilitation programs are scarce (2). The results therefore support the integration of routine post-meningitis hearing assessments into national pediatric care pathways. Early rehabilitation using hearing aids, cochlear implantation, or structured speech therapy can mitigate long-term disability, but these interventions depend on timely detection. The strong representation of cases among children aged 0–3 years further underscores the developmental urgency, as even short delays in diagnosis may have lifelong consequences.

This study contributes to the regional evidence base by providing robust local prevalence estimates using a comprehensive battery of audiological tools, which strengthens internal validity and reproducibility. The methodological strengths include strict eligibility criteria to exclude confounding auditory conditions, the use of both behavioral and objective measures of hearing, and blinding of audiologists to reduce observer bias. However, several limitations must be acknowledged. The purposive sampling strategy, while practical in a hospital setting, restricts generalizability to the wider pediatric population. The cross-sectional design precludes assessment of temporal progression, although previous work has demonstrated that hearing loss after meningitis may evolve over time (15). Furthermore, the lack of microbiological stratification limits pathogen-specific interpretation, and the absence of long-term follow-up prevents evaluation of rehabilitation outcomes.

Despite these limitations, the findings carry important theoretical and practical implications. They confirm that meningitis remains a leading cause of post-infectious hearing loss in children, consistent with prior reports (4,5,14). They also suggest that the true burden in South Asia may be underestimated due to under-screening and lack of systematic follow-up. Future research should therefore focus on multicenter, longitudinal designs incorporating microbiological profiling, treatment timelines, and vaccination status to clarify predictors of severity and laterality.

Additionally, cost-effectiveness analyses of universal post-meningitis hearing screening would be valuable in informing health policy in resource-limited settings.

CONCLUSION

This study demonstrated that hearing loss is a frequent sequela of pediatric meningitis, affecting nearly two-thirds of children, with moderate impairment being the most prevalent and profound loss observed in a substantial minority. These findings confirm that meningitis remains a major contributor to post-infectious auditory disability in children, consistent with global evidence, and underscore the critical need for routine post-meningitis hearing assessments in clinical practice. From a healthcare perspective, early identification and timely rehabilitation through hearing aids, cochlear implantation, and speech therapy are essential to mitigate long-term developmental, educational, and psychosocial consequences. At the research level, the results highlight the importance of longitudinal, multicenter studies to better define pathogen-specific risks, track the progression of auditory impairment over time, and evaluate the effectiveness and cost-efficiency of structured screening programs in resource-limited settings, thereby informing evidence-based guidelines for pediatric meningitis management in South Asia and beyond.

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