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Original Article

Auditory Outcomes in Neonates Born to Mothers with Preeclampsia: A Cross-Sectional Study

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ABSTRACT

Background: Neonatal hearing loss is a major global health concern, with an estimated incidence of 1–5 per 1000 live births. Maternal preeclampsia has been proposed as a risk factor due to uteroplacental insufficiency and intrauterine hypoxia, but limited evidence exists from low- and middle-income countries. Early detection through otoacoustic emissions (OAEs) is crucial to prevent long-term deficits in speech, cognition, and psychosocial development. Objective: To determine the frequency of hearing loss in neonates born to mothers with preeclampsia and explore associated maternal and neonatal factors. Methods: A cross-sectional observational study was conducted at the University of Lahore Teaching Hospital between March and September 2023. A total of 173 neonates of preeclamptic mothers were enrolled consecutively. Bilateral distortion product otoacoustic emissions (DPOAEs) were recorded within 48 hours of birth. Maternal and neonatal data were collected, and associations with OAE outcomes were analyzed using chi-square tests and odds ratios with 95% confidence intervals. Results: Forty neonates (23.1%) demonstrated absent bilateral DPOAE responses. Low birth weight was associated with a higher refer rate (30.8% vs 20.9%, OR 1.68, 95% CI: 0.74–3.81; p=0.21), though not statistically significant. Maternal comorbidities, infections, delivery mode, and neonatal sex showed no significant associations. Conclusion: Neonates of preeclamptic mothers demonstrated a high prevalence of abnormal OAE outcomes, indicating increased risk of early auditory dysfunction. Routine neonatal hearing screening should be prioritized in this high-risk group to enable timely intervention. Keywords: Neonatal hearing loss; Preeclampsia; Distortion product otoacoustic emissions; Low birth weight; Newborn screening.

INTRODUCTION

Hearing loss in neonates represents a significant global health challenge with profound consequences for language development, academic achievement, and social integration. Congenital or early-onset hearing impairment occurs in approximately 1–5 per 1000 live births, with prevalence rising to 8 per 1000 when unilateral cases are included (1). According to the World Health Organization, more than 466 million people worldwide live with disabling hearing loss, of whom an estimated 34 million are children, and this burden is projected to rise to nearly 900 million individuals by 2050 (2). Early detection of neonatal hearing impairment is essential, as delays in diagnosis and intervention can lead to irreversible deficits in speech, cognitive, and psychosocial development (3). Despite advances in universal newborn hearing screening, disparities persist in resource-limited settings, where systematic protocols are inconsistently applied.

The clinical spectrum of congenital hearing loss is heterogeneous, encompassing genetic syndromes, intrauterine infections, prematurity, low birth weight, and maternal comorbidities. Among these, maternal preeclampsia has increasingly been recognized as a potential risk factor (4). Preeclampsia, a hypertensive disorder of pregnancy defined by new-onset hypertension and proteinuria after 20 weeks of gestation, complicates 2–10% of pregnancies worldwide, with incidence rates reaching as high as 16.7% in some developing countries (5). In Pakistan, prevalence estimates range from 5–8%, underscoring the magnitude of this condition in local obstetric practice (6). The pathophysiology of preeclampsia involves abnormal placentation, endothelial dysfunction, and uteroplacental ischemia, all of which may compromise intrauterine growth and fetal organ development, including the auditory system (7).

Otoacoustic emissions (OAEs), particularly distortion product otoacoustic emissions (DPOAEs), are widely used for neonatal hearing screening as they provide an objective, non-invasive measure of cochlear outer hair cell function (8). Infants with hearing thresholds exceeding 25–30 dB typically fail to generate OAE responses, thereby facilitating the early detection of subclinical or overt auditory deficits (9). Several international studies have reported an elevated risk of absent OAEs in neonates born to preeclamptic mothers, with prevalence estimates ranging from 23% to over 50% depending on the study population and screening methodology (10–12). However, other investigations have demonstrated lower frequencies or non-significant associations, highlighting the need for context-specific evidence (13).

Despite global progress in understanding the association between maternal preeclampsia and neonatal hearing loss, research in South Asia—and particularly in Pakistan—remains sparse. Most existing studies originate from high-income countries with well-established neonatal screening programs, limiting generalizability to low- and middle-income contexts. Furthermore, variability in diagnostic criteria, exclusion of important confounders, and differences in screening protocols create inconsistencies in reported outcomes. Addressing this gap is essential for developing targeted screening strategies and guiding preventive measures in high-risk maternal populations.

The present study was therefore designed to determine the frequency of hearing loss in neonates born to preeclamptic women in Pakistan. We hypothesized that neonates of preeclamptic mothers would demonstrate a significantly higher prevalence of absent DPOAE responses, reflecting compromised auditory function. By quantifying this risk, the study aims to provide evidence to support the inclusion of high-risk neonatal groups in universal screening programs and to inform clinical practices in maternal-fetal medicine.

MATERIAL AND METHODS

This study employed a descriptive cross-sectional observational design to determine the frequency of hearing loss in neonates born to mothers diagnosed with preeclampsia. A cross-sectional approach was selected because it permits the estimation of prevalence and associations within a defined population at a single point in time, which is appropriate for evaluating neonatal outcomes of a pregnancy-specific condition (14). The research was conducted at the University of Lahore Teaching Hospital, with data collection carried out prospectively between 1 March 2023 and 30 September 2023. Participants were recruited from Hameed Latif Hospital, Lahore, a tertiary care referral center with a high delivery volume and specialized obstetric care, thereby ensuring representative access to neonates of preeclamptic mothers.

Eligibility criteria encompassed all live-born neonates of both sexes delivered to mothers clinically diagnosed with preeclampsia after 20 weeks of gestation. Diagnosis of preeclampsia was based on established obstetric criteria, including elevated blood pressure and proteinuria, in line with internationally recognized definitions (15). Neonates were included if they achieved an Apgar score above 6 at five minutes post-delivery and did not demonstrate clinical evidence of perinatal asphyxia. Prenatal comorbidities such as maternal gestational diabetes or hypothyroidism were not exclusionary provided the mother had a concurrent diagnosis of preeclampsia, as the focus remained on the preeclampsia–hearing loss relationship. Exclusion criteria were implemented to reduce confounding from independent causes of neonatal auditory dysfunction and included congenital TORCH infections, Rh isoimmunization, cerebral palsy, severe perinatal asphyxia, and postnatal complications such as neonatal meningitis, sepsis, encephalitis, pneumonia, or head trauma (16).

A consecutive sampling method was applied, whereby all eligible neonates born during the study period were approached for enrollment until the target sample size was achieved. Sample size was calculated a priori using the prevalence estimate reported by Bakhshaee et al., who identified hearing loss in one-third of neonates born to preeclamptic women (17). Using this prevalence as a reference, a 95% confidence level, and an acceptable margin of error of 7%, the minimum required sample size was calculated to be 160. To account for potential attrition or incomplete data, 173 neonates were ultimately enrolled. Written informed consent was obtained from mothers or legal guardians after explanation of study procedures and confidentiality safeguards.

Data were collected using a structured 15-item proforma designed for the study. Maternal variables included age, gestational age at delivery, parity, comorbid conditions, infections during pregnancy, and mode of delivery. Neonatal variables included sex, birth weight, Apgar score, and perinatal clinical stability. Hearing assessment was performed using Distortion Product Otoacoustic Emissions (DPOAE) testing, a validated non-invasive method for evaluating cochlear outer hair cell function (18). The test was administered bilaterally within the first 48 hours of life by trained audiology personnel using a calibrated otoacoustic emission analyzer under standardized environmental conditions. A miniature probe was inserted into the external ear canal to deliver two simultaneous pure-tone stimuli and measure the resulting otoacoustic emissions. The results were automatically displayed on the device as “pass” (indicating intact cochlear function) or “refer” (suggestive of impaired function). Neonates were categorized according to the outcome of this screening.

To minimize bias, uniform protocols were followed across all cases. Testing was conducted in a quiet environment, and device calibration was verified daily. Inter-observer variability was reduced by restricting DPOAE administration to two trained audiologists who alternated in performing tests. Consecutive sampling reduced selection bias, while exclusion of neonates with known alternative risk factors for hearing loss minimized confounding.

Data were entered into IBM SPSS Statistics version 25 for analysis. Continuous variables such as maternal age and gestational age were expressed as means with standard deviations, while categorical variables such as neonatal sex, birth weight category, and OAE outcomes were reported as frequencies and percentages. Associations between maternal and neonatal factors and OAE outcomes were assessed using chi-square tests. Odds ratios with 95% confidence intervals were calculated to quantify effect sizes. A two-sided p-value <0.05 was considered statistically significant. Missing data were handled using complete-case analysis, as all enrolled participants had complete

datasets. No imputation was required. Subgroup analyses were performed to evaluate potential interactions by neonatal sex and birth weight.

The study was reviewed and approved by the Ethical Review Committee of the University of Lahore (reference number provided by institutional records). All procedures complied with the Declaration of Helsinki and national ethical guidelines for research involving human participants (19). Measures to ensure data integrity included double-entry of data, cross-checking against proforma records, and secure password-protected storage of datasets. The detailed reporting of eligibility criteria, standardized testing protocols, and analytic procedures supports reproducibility and external validation of findings.

RESULTS

The maternal and neonatal characteristics are summarized in Table 1. The mothers in this study had a mean age of 31.5 years (SD 3.6, range 26–40). Nearly three-quarters of mothers (127/173, 73.4%) had no comorbid illnesses, while gestational diabetes mellitus was the most common condition, present in 38 cases (22.0%). Only four mothers (2.3%) each had either pregestational diabetes or hypothyroidism. Maternal infections during pregnancy were rare, affecting 4/173 women (2.3%). Cesarean section was the predominant mode of delivery, accounting for 157/173 births (90.8%), whereas only 16 neonates (9.2%) were delivered vaginally. Among the neonates, 102 (59.0%) were male and 71 (41.0%) were female. The mean gestational age at delivery was 36.8 weeks (SD 1.5, range 33–39). Low birth weight (<2.5 kg) was observed in 39 neonates (22.5%), while the majority (134/173, 77.5%) had normal birth weight. Importantly, all neonates achieved normal Apgar scores at five minutes, and none required NICU admission, reflecting good overall clinical stability despite maternal preeclampsia.

Table 2 presents the otoacoustic emission outcomes. Of the 173 neonates, 133 (76.9%) successfully passed DPOAE screening bilaterally, while 40 (23.1%) exhibited absent responses in both ears. The identical proportions of refer outcomes in the right and left ears (23.1% each) underscore the bilateral nature of auditory dysfunction in this population. The relatively high prevalence of abnormal responses highlights the potential vulnerability of neonates born to preeclamptic mothers.

Associations between maternal and neonatal variables and OAE outcomes are outlined in Table 3. Neonates of mothers with comorbid illnesses demonstrated a lower refer rate (8/46, 17.4%) compared to those without comorbidities (32/127, 23.9%), although the difference was not statistically significant (p = 0.29, OR 0.67, 95% CI: 0.28–1.60). Similarly, maternal infection did not significantly influence outcomes, with one of four neonates (25.0%) failing OAE screening compared to 23.1% of those without infection (p = 0.93, OR 1.13, 95% CI: 0.11–11.1).

Table 1. Maternal and Neonatal Characteristics (n = 173)

Variable	Mean ± SD / n (%)
Maternal age (years)	31.52 ± 3.55
Gestational age (weeks)	36.79 ± 1.49
Maternal illness	None: 127 (73.4%) / GDM: 38 (22.0%) / DM: 4 (2.3%) / Hypothyroidism: 4 (2.3%)
Maternal infection	Yes: 4 (2.3%) / No: 169 (97.7%)
Mode of delivery	Cesarean: 157 (90.8%) / Vaginal: 16 (9.2%)
Neonatal sex	Male: 102 (59.0%) / Female: 71 (41.0%)
Birth weight	Normal (≥2.5 kg): 134 (77.5%) / Low (<2.5 kg): 39 (22.5%)
Apgar score	Normal: 173 (100%)
NICU admission	No: 173 (100%)

Table 2. Otoacoustic Emission (OAE) Results by Ear

OAE Result	Right Ear n (%)	Left Ear n (%)	Bilateral "Refer" n (%)
Pass	133 (76.9)	133 (76.9)	—
Refer	40 (23.1)	40 (23.1)	40 (23.1)

Table 3. Associations Between Maternal and Neonatal Factors and OAE Outcomes

Variable	Pass OAE n (%)	Refer OAE n (%)	p-value	OR (95% CI)
Maternal illness (any)	38/46 (82.6)	8/46 (17.4)	0.29	0.67 (0.28–1.60)
Maternal infection	3/4 (75.0)	1/4 (25.0)	0.93	1.13 (0.11–11.1)
Mode of delivery (C/S vs Vag)	122/157 (77.7) vs 11/16 (68.8)	35/157 (22.3) vs 5/16 (31.2)	0.39	1.57 (0.48–5.11)
Neonatal sex (male vs female)	79/102 (77.5) vs 54/71 (76.1)	23/102 (22.5) vs 17/71 (23.9)	0.84	1.08 (0.52–2.25)
Birth weight (normal vs LBW)	106/134 (79.1) vs 27/39 (69.2)	28/134 (20.9) vs 12/39 (30.8)	0.21	1.68 (0.74–3.81)

Mode of delivery demonstrated a non-significant trend: 22.3% of neonates delivered via cesarean section (35/157) exhibited absent DPOAEs compared to 31.2% of vaginally delivered neonates (5/16) (p = 0.39, OR 1.57, 95% CI: 0.48–5.11). Neonatal sex did not affect outcomes, with nearly identical refer rates among males (23/102, 22.5%) and females (17/71, 23.9%) (p = 0.84, OR 1.08, 95% CI: 0.52–2.25).

Birth weight showed the strongest clinical trend. Low-birth-weight neonates had a higher proportion of refer outcomes (12/39, 30.8%) compared with normal-weight neonates (28/134, 20.9%). Although the association did not reach statistical significance (p = 0.21), the odds

ratio of 1.68 (95% CI: 0.74–3.81) suggests that low birth weight may increase the risk of impaired cochlear responses in neonates of preeclamptic mothers. Taken together, the findings reveal that nearly one in four neonates of preeclamptic mothers demonstrate abnormal DPOAE responses, with low birth weight emerging as a potentially important risk factor. While none of the associations with maternal comorbidities, infection, delivery mode, or sex reached statistical significance, the observed trends point toward clinically meaningful patterns that warrant further investigation in larger, multicenter cohorts.

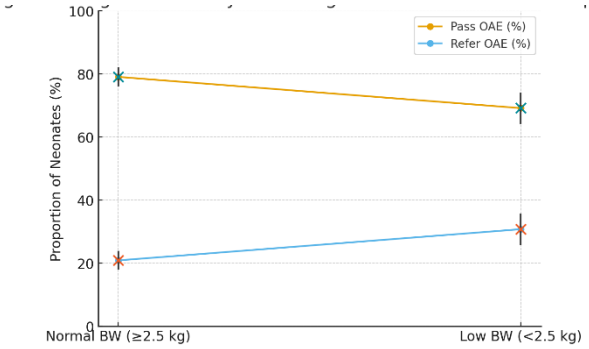

Figure 1 Hearing Screening Outcomes by Birth Weight in Neonates of Preeclamptic Mothers

The visualization compares otoacoustic emission screening outcomes between neonates with normal birth weight (≥2.5 kg) and those with low birth weight (<2.5 kg). Among normal-weight infants, 79.1% passed screening while 20.9% were referred, whereas in low-birth-weight infants, the pass rate decreased to 69.2% with a corresponding rise in refer outcomes to 30.8%. The plotted trend line demonstrates a downward trajectory for pass rates and an upward trajectory for refer rates as birth weight decreases. Error bars indicate wider variability in outcomes among low-birth-weight neonates, emphasizing the potential clinical impact of intrauterine growth restriction on auditory function. This pattern, though not statistically significant, suggests that birth weight may play an amplifying role in the relationship between maternal preeclampsia and neonatal auditory dysfunction.

DISCUSSION

This study identified a 23.1% prevalence of absent bilateral DPOAE responses in neonates born to mothers with preeclampsia, underscoring a clinically important risk of early auditory dysfunction in this high-risk group. The observed prevalence aligns closely with previous work by Samanth et al., who reported abnormal OAE responses in 23.3% of neonates from preeclamptic pregnancies (20). By contrast, Bakhshaee et al. reported a higher prevalence approaching one-third of cases (21), while Amer et al. observed failure rates exceeding 50% (22). These discrepancies likely reflect heterogeneity in study designs, population demographics, diagnostic thresholds, and timing of auditory screening. Importantly, our exclusion of neonates with other recognized risk factors such as TORCH infections, severe perinatal asphyxia, and NICU admissions may explain the relatively lower prevalence compared with some prior studies.

The bilateral nature of OAE absence in our cohort is biologically plausible, as preeclampsia is associated with uteroplacental insufficiency and chronic intrauterine hypoxia, which may disrupt cochlear development and auditory neural maturation (23). Evidence from animal studies supports the hypothesis that hypoxic-ischemic injury to the cochlear outer hair cells and stria vascularis may underlie sensorineural deficits (24). Furthermore, the trend toward higher refer rates among low-birth-weight neonates in our study is consistent with the established association between intrauterine growth restriction, prematurity, and sensorineural hearing impairment (25). Although the odds ratio of 1.68 did not reach statistical significance, the clinical relevance of this finding cannot be overlooked, as small differences in early cochlear dysfunction may translate into long-term deficits if unrecognized.

Contrary to expectations, maternal comorbidities such as gestational diabetes and hypothyroidism did not demonstrate significant associations with neonatal hearing outcomes in this cohort. Previous studies have suggested that gestational diabetes may exacerbate intrauterine hypoxia and microvascular dysfunction, potentially increasing risk of hearing impairment (26). The lack of association in our analysis may be due to the homogeneity of the preeclamptic population, wherein the dominant effect of preeclampsia overshadowed secondary influences. Similarly, mode of delivery was not associated with OAE outcomes, despite literature linking cesarean birth with transient middle ear effusion and higher referral rates in early neonatal screening (27). These null findings highlight the complex interplay of maternal, fetal, and delivery-related factors, suggesting that preeclampsia itself may constitute an independent risk factor of sufficient magnitude to mask smaller contributions from comorbidities or birth-related variables.

The clinical implications of these findings are substantial. Neonatal hearing loss, even when transient or mild, can have profound effects on speech, language, and cognitive development if not detected and managed promptly (28). Universal newborn hearing screening is increasingly recognized as essential, yet coverage in resource-limited countries remains incomplete. Our findings strengthen the argument for prioritizing high-risk groups—particularly neonates of preeclamptic mothers—for systematic auditory screening in the early postnatal period. The use of non-invasive and cost-effective tools such as DPOAEs makes such targeted screening feasible in low- and middle-income settings (29). Moreover, early detection could facilitate timely interventions, including hearing amplification, speech therapy, or cochlear implantation, thereby mitigating long-term developmental consequences.

This study contributes important local evidence but is not without limitations. Its single-center design and use of consecutive sampling may restrict generalizability to broader populations. Residual confounding by unmeasured variables such as maternal nutritional status,

environmental exposures, and genetic predispositions cannot be excluded. Additionally, auditory outcomes were assessed only in the immediate neonatal period; longer-term follow-up using confirmatory auditory brainstem response testing would be necessary to determine persistence of deficits and to differentiate transient from permanent impairments. Despite these limitations, the rigorous exclusion of alternative risk factors, standardized DPOAE protocols, and relatively large sample size strengthen the internal validity of the findings.

In summary, the present study adds to growing evidence that maternal preeclampsia is independently associated with an elevated risk of neonatal auditory dysfunction. The strong clinical trends observed in relation to low birth weight further emphasize the biological plausibility of this association. Our results support the need for universal newborn hearing screening with particular emphasis on neonates from preeclamptic pregnancies. Future multicenter longitudinal studies incorporating both OAE and ABR testing are warranted to clarify causal pathways and to inform national screening guidelines, particularly in resource-limited settings where the burden of preeclampsia and neonatal hearing loss is disproportionately high.

CONCLUSION

This study demonstrated that nearly one in four neonates born to mothers with preeclampsia exhibited absent bilateral DPOAE responses, indicating a significant burden of early auditory dysfunction in this population. Although associations with maternal comorbidities, neonatal sex, and mode of delivery were not statistically significant, low birth weight emerged as a clinically relevant trend, suggesting a possible amplifying effect on auditory risk. These findings reinforce maternal preeclampsia as an independent risk factor for neonatal hearing loss and highlight the importance of targeted newborn auditory screening in high-risk groups. Incorporating systematic OAE-based screening into obstetric and neonatal care pathways may enable early identification and timely intervention, thereby mitigating long-term developmental consequences. Future multicenter longitudinal studies with confirmatory diagnostic tools are warranted to validate these associations and guide evidence-based screening policies in resource-limited settings.

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