Outcome of Hearing Screening using Automated Auditory Brainstem Response (AABR) in Neonates Delivered through High Risk Pregnancies in Dhulikhel Hospital

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ABSTRACT

Background

High-risk pregnancies increase the likelihood of neonatal hearing impairment, yet early signs are often subtle or absent, delaying diagnosis. Early identification through newborn hearing screening is critical to prevent long-term auditory and developmental deficits.

Objective

To evaluate neonatal hearing screening outcomes using Automated Auditory Brainstem Response (AABR) in neonates born through high-risk pregnancies at Dhulikhel Hospital.

Method

In this prospective study, neonates born between 15th March 2023 and 15th September 2024 through high-risk pregnancies were screened using Automated auditory brainstem response within 24 hours of birth. Neonates failing the initial screening were re-tested at six weeks. Maternal risk factors including hypothyroidism, diabetes, hypertension, pre-eclampsia, renal disorders, STDs, psychiatric disorders, heart disease, smoking, and extreme maternal age were recorded. Neonates failing the second screening were referred and tested with diagnostic automated auditory brainstem response .

Result

Ninety neonates (41 males, 49 females) were included. Thirty-two neonates failed the initial automated auditory brainstem response , and nine failed the second screening, yielding a referral rate of 10%. Maternal hypothyroidism was the most common risk factor among referred cases. Other maternal factors associated with referrals included diabetes, maternal age ≥ 35 years, pre-eclampsia, smoking, and STDs. The overall diagnostic automated auditory brainstem response failure rate was 3.3%, highlighting the low but significant prevalence of hearing impairment among high-risk pregnancies.

Conclusion

Maternal health conditions, particularly hypothyroidism, diabetes, and advanced maternal age, are associated with increased risk of neonatal hearing impairment. automated auditory brainstem response is an effective screening tool in high-risk populations, and early detection with timely intervention is essential to optimize auditory and developmental outcomes.

KEY WORDS

Automated auditory brainstem response (AABR), Congenital hearing loss, High-risk pregnancy, Maternal risk factors, Neonatal hearing screening, Universal newborn hearing screening (UNHS)

INTRODUCTION

Hearing loss, defined as an auditory threshold of 25 dB or more in both ears, can range from mild to profound and may affect one or both ears, leading to difficulties in perceiving speech and environmental sounds.[1] Individuals with mild-to-severe hearing loss, often termed "hard of hearing," typically communicate through spoken language and benefit from hearing aids, cochlear implants, and other assistive devices, whereas those with profound hearing loss often rely on sign language.[1] Congenital hearing loss, present at birth, is among the most common chronic conditions in children, arising from genetic, prenatal, environmental, or infectious causes.[2]

Globally, permanent bilateral sensorineural hearing loss ≥ 40 dB occurs in approximately 1-3 per 1,000 live births. According to the World Health Organization, the number of individuals with hearing loss has more than doubled from 120 million in 1995 to 278 million in 2005, with projections reaching 2.5 billion by 2050.[2-6]

High-risk pregnancies defined by maternal age extremes, medical comorbidities, obstetric complications, or socioeconomic factors are associated with a higher prevalence of congenital hearing loss compared to normal pregnancies.[7] Early detection through newborn hearing screening, using methods such as automated Auditory Brainstem Response (AABR) is crucial for timely intervention and optimal language development.[8-10] While universal newborn hearing screening programs are well-established in many developed countries, such initiatives are limited in Nepal.[11] Implementing even small-scale screening programs for both high-risk and normal newborns can significantly enhance early identification, intervention, and long-term outcomes, underscoring the importance of targeted hearing healthcare initiatives in this population.

METHODS

This was a hospital-based prospective observational study conducted at Dhulikhel Hospital, Kathmandu University Hospital (KUH) from 15th March 2023 to 15th September 2024. The study was conducted collaboratively across the Postnatal Ward of the Obstetrics and Gynaecology Department, the Neonatal Intensive Care Unit (NICU) of the Pediatrics Department, and the Ear, Nose, Throat - Head and Neck Surgery (ENT-HNS) and Audiology Unit. Initial hearing screening was performed in the postnatal ward or NICU, with follow-up assessments conducted in the Ear, Nose, Throat - Head and Neck Surgery (ENT-HNS) and Audiology Unit outpatient department (OPD).

Inclusion Criteria

• Neonates delivered through high-risk pregnancies at Dhulikhel Hospital and screened ≥ 12 hours after birth.

• Neonates admitted to the NICU from high-risk pregnancies with a stay > 5 days.

• Neonates with documented maternal risk factors.

Exclusion Criteria

• Neonates whose guardians did not provide consent or were lost to follow-up.

• Unstable neonates unable to undergo hearing screening.

Data Collection and Hearing Assessment

Parents were counseled on the procedure, benefits of early detection, follow-up requirements, and potential interventions. Detailed case histories were recorded, including maternal history, perinatal and postnatal details, family history, and specific high-risk factors. Neonates underwent ENT examination to identify outer and middle ear anomalies. Screening was performed in acoustically quiet environments using Automated Auditory Brainstem Response (AABR). Neonates receiving a "refer" result on initial screening were re-tested at six weeks. Infants who failed the second screening were referred for comprehensive diagnostic ABR.

Diagnostic ABR was performed using the Labat Epic Plus-ABR system under natural sleep conditions. The following ABR protocol was used for screening.

ABR Protocol

• Stimulus: Clicks

• Intensity: Varying intensity for threshold estimation

• Polarity: Alternating

• Number of clicks: 2000

• Time window: 15 ms

• Filter settings: 100–3000 Hz

• Electrode montage: Cz – M1/M2 with FPz as ground

• Electrode impedance: <5 kΩ with inter-electrode difference < 2 kΩ

• Threshold definition: Lowest stimulus intensity producing a replicable Wave V response.

Data were analyzed using SPSS version 25. Chi-square and fisher's exact test tests were applied to assess associations between maternal risk factors and referral outcomes, with significance set at $p < 0.05$.

Ethical approval was obtained from the Ethics and Research Committee, KUSMS (241/22). Written informed consent was obtained from guardians after detailed explanation of the study, potential outcomes, and the right to withdraw at any time.

RESULTS

A total of 90 neonates born to mothers with high-risk pregnancies underwent AABR screening. Of these, 41 (46%) were male and 49 (54%) were female.

On the first AABR screening, 58 (64.4%) neonates passed, while 32 (35.6%) were referred. Of those referred, 9 (10.0% of total) remained referred on the second screening. Ultimately, 2 neonates (3.3%) failed diagnostic ABR, confirming permanent hearing loss.

When analyzed according to maternal risk factors, referral and failure patterns showed distinct variations (Table 1). Maternal hypothyroidism (27.8%) and diabetes (18.9%) were the most common comorbidities. Neonates of mothers with STDs, hypothyroidism, and advanced maternal age (≥ 35 years) were more frequently associated with diagnostic ABR failure, though the absolute numbers were small.

Table 1. Distribution of ABR results according to maternal risk factors

Maternal risk factor	Pass n (%)	First Refer n (%)	Second Refer n (%)	Diagnostic ABR Fail n (%)	Total n (%)
Maternal STDs	1(1.7)	1 (3.1)	1 (11.1)	1 (33.3)	2(2.2)
Maternal renal disorders	2(3.4)	1 (3.1)	0	0	3(3.3)
Maternal diabetes	12 (20.7)	5 (15.6)	1 (11.1)	0	17 (18.9)
Maternal hyperthyroidism	2 (3.4)	1 (3.1)	0	0	3(3.3)
Maternal hypothyroidism	17 (29.3)	8 (25.0)	1 (11.1)	1 (33.3)	25 (27.8)
Pregnancy ≥ 35 years	3 (5.2)	3 (9.4)	1 (11.1)	1 (33.3)	6(6.7)
Pregnancy ≤ 16 years	3 (5.2)	2 (6.3)	0	0	5 (5.6)
Maternal preeclampsia	3 (5.2)	2 (6.3)	0	0	5 (5.6)
History of miscarriage	4 (6.9)	2 (6.3)	1 (11.1)	0	6(6.7)
Maternal smoking	0	2 (6.3)	2 (22.2)	0	2(2.2)
Maternal psychiatric disorder	2 (3.4)	1 (3.1)	0	0	3(3.3)
Maternal heart disease	3 (5.2)	1 (3.1)	1 (11.1)	0	4(4.4)
Maternal hypertension	6 (10.3)	3 (9.4)	1 (11.1)	0	9 (10.0)
Total	58	32	9	3	90

Overall, while referral rates were relatively high among several maternal risk groups, the confirmed diagnostic ABR failure rate remained low (3.3%) in this high-risk population.

Association with Diagnostic ABR Failure

Fisher's exact test was applied as shown in table 2. Maternal STDs (OR 43.0, p = 0.066) and advanced maternal age (≥35 years; OR 8.2, p = 0.189) showed trends toward higher risk of diagnostic failure, although these did not reach statistical significance due to small sample size. Hypothyroidism was associated with one confirmed failure (4.0%), but without statistical significance (p = 1.0).

Association with Referral (any stage)

Table 2. Association of maternal risk factors with diagnostic ABR failure

Risk factor	Fail/Total	Odds ratio	p-value (Fisher's)
Maternal STDs	1/2	43.0	0.066
Maternal hypothyroidism	1/25	1.31	1.000
Pregnancy ≥ 35 years	1/6	8.20	0.189
Others (renal, diabetes, HTN, etc.)	0/group	–	–

Referral (including first, second, and fail) was compared to "Pass" outcomes as shown in table 3. Maternal smoking showed a near-significant association (p = 0.076), as all neonates born to smoking mothers were referred. Other risk factors, including diabetes, hypothyroidism, and hypertension, showed elevated referral rates but without statistical significance (p > 0.05).

Table 3. Association of maternal risk factors with referral (any stage) Vs. pass

Risk factor	Referral or Fail n (%)	Pass n (%)	p-value (Chi-square/ Fisher's)
Maternal STDs	1 (50.0)	1 (50.0)	0.234
Maternal diabetes	5 (29.4)	12 (70.6)	0.446
Maternal hypothyroidism	8 (32.0)	17 (68.0)	0.516
Pregnancy ≥ 35 years	3 (50.0)	3 (50.0)	0.286
Maternal smoking	2 (100.0)	0 (0.0)	0.076
Other groups	Variable	–	> 0.05

So the key findings were

- Overall diagnostic ABR failure rate was 3.3% in high-risk neonates.
- Maternal STDs and advanced age showed strong trends toward higher failure, though not statistically significant.
- Maternal smoking was strongly associated with higher referral rates (p ≈ 0.076).
- Hypothyroidism and diabetes increased referrals but rarely progressed to confirmed failure.

DISCUSSIONS

In the present study, 90 neonates born to mothers with high-risk pregnancies were screened with AABR. Of these, 64.4% passed the initial screening, 35.6% required a first repeat, 10.0% required a second repeat, and ultimately 3 neonates (3.3%) failed diagnostic ABR. While the overall

diagnostic fail rate was low, the distribution of referrals within specific maternal risk categories reveals important trends. Understanding these associations is crucial because maternal comorbidities may not only predispose to congenital hearing loss but also to transient or progressive auditory dysfunction that requires structured follow-up.

These findings are broadly consistent with reports from global literature. Siddique et al. found that approximately 2% of high-risk neonates had bilateral severe sensorineural hearing loss, aligning closely with our results.[12] Similarly, Labaeka et al. demonstrated high referral rates among high-risk newborns on initial screening (~41%), which decreased to 9.5% after repeat testing, mirroring the trend observed in our study where referrals dropped substantially after the second screen.[13] A systematic review and meta-analysis by Butcher et al. reported a pooled prevalence of permanent childhood hearing loss of ~1.1 per 1000 live births in general populations, but significantly higher in neonatal intensive care unit (NICU) and high-risk groups.[14] Our higher prevalence compared with general newborn populations is expected, given the targeted high-risk maternal group.

Studies from India and other regions have also shown higher rates of hearing loss among high-risk infants. Rawat et al. reported an incidence of 18.3 per 1000 in high-risk neonates compared with 5.3 per 1000 among well babies, highlighting the strong impact of maternal and perinatal risk factors.[15] Our study corroborates these findings, reinforcing the need for vigilant screening in high-risk pregnancies.

Maternal infections

Infants of mothers with sexually transmitted diseases (STDs) or other infections demonstrated the highest proportion of diagnostic ABR failures in our study. This finding aligns with the established role of congenital infections, particularly cytomegalovirus (CMV), syphilis, and rubella, as significant causes of sensorineural hearing loss in newborns.[2,16] Korver et al. reported that congenital CMV accounts for nearly 20% of bilateral moderate-to-profound hearing loss worldwide.[2] The underlying pathophysiology involves viral invasion of the cochlea and central auditory pathways, often resulting in progressive loss, even in children who initially pass newborn screening.[16] Our results, although based on small numbers, reinforce that maternal infection remains a red flag for irreversible hearing deficits and justify mandatory diagnostic ABR follow-up in such cases.

The associations observed between maternal STDs and hearing outcomes are biologically plausible. Prenatal infections such as syphilis, toxoplasmosis, rubella, and cytomegalovirus are established risk factors for congenital hearing loss. Besen et al. demonstrated that infants with congenital syphilis were 3.25 times more likely to fail neonatal hearing screening than those without syphilis.[17] Similarly, Oliveira et al. confirmed congenital syphilis as a significant risk indicator for hearing impairment in newborns.[18] Although our study had small numbers, the markedly elevated odds ratio for STDs (OR 43.0, p = 0.066) suggests a strong association that may achieve significance in larger cohorts.

Maternal thyroid disorders

Hypothyroidism during pregnancy was a prominent risk factor in our study, with higher referral rates though only one case progressed to diagnostic failure. Thyroid hormones play a central role in neuronal maturation, myelination, and cochlear development. Evidence suggests that untreated or inadequately corrected maternal hypothyroidism is associated with delayed auditory brainstem responses in neonates, indicating slowed neural conduction along the auditory pathway.[19] However, when hypothyroidism is detected early and adequately managed, the adverse impact on hearing outcomes is substantially reduced. Varsha I et al. demonstrated normalization of ABR latencies in infants of treated hypothyroid mothers over time.[19] This could explain why our hypothyroid group showed elevated referrals likely reflecting transient maturational delays yet low rates of permanent failure.

Maternal diabetes

In our study, neonates of diabetic mothers showed increased referral rates but no confirmed diagnostic ABR failures. This observation is consistent with Amrutha et al. who reported that neonates of diabetic mothers had higher odds of abnormal initial hearing screens; though permanent impairment was uncommon.[20] Proposed mechanisms include hyperglycemia-induced microangiopathy affecting cochlear blood supply and intrauterine hypoxia contributing to temporary auditory dysfunction. Importantly, good maternal glycemic control has been shown to mitigate risk, suggesting that improvements in antenatal diabetic management may explain the absence of confirmed failures in our study. Nevertheless, these neonates remain at increased risk for late-onset auditory dysfunction and warrant close audiological surveillance.

Maternal hypertension and preeclampsia

Hypertensive disorders of pregnancy, including preeclampsia, were also associated with increased referrals but not with diagnostic failures. Maternal hypertension reduces placental blood flow, leading to chronic fetal hypoxia, which can affect cochlear function and neural transmission. A recent study by Samanth et al. found that infants of preeclamptic mothers had significantly abnormal otoacoustic emissions compared with controls, although many resolved spontaneously within weeks.[21] This is consistent with our findings, where transient dysfunction rather than permanent loss appeared more likely. These results highlight that vascular and hypoxic influences during pregnancy may manifest as temporary auditory pathway immaturity rather than irreversible damage.

Maternal smoking

Although only two mothers in our series reported smoking during pregnancy, both neonates were referred on AABR. The role of prenatal tobacco exposure in auditory dysfunction is increasingly recognized. Weitzman et al. demonstrated that maternal smoking during pregnancy significantly increased the risk of adolescent hearing loss, suggesting long-term cochlear vulnerability.16 Mechanistically, smoking induces fetal hypoxia, oxidative stress, and vascular compromise, which may impair inner ear development.

The strong association of maternal smoking with referral in our data, although not statistically significant due to small numbers, is noteworthy. Evidence on smoking and neonatal hearing outcomes remains mixed, but mechanisms such as intrauterine hypoxia and vascular compromise could plausibly affect auditory development. Larger studies are warranted to further elucidate this relationship.

The lack of statistical significance for many associations in our study likely reflects the limited sample size, which reduced power to detect moderate effects. Nevertheless, the large effect sizes observed for STDs and maternal age suggest clinically relevant trends. Strengths of our study include its focus on maternal risk factors, which remain under-represented in much of the neonatal hearing screening literature. Limitations include small subgroup numbers, potential selection bias, and lack of long-term follow-up to detect delayed-onset hearing loss.

CONCLUSION

Our study shows that while the overall diagnostic ABR failure rate was low (3.3%), maternal comorbidities strongly influenced referral patterns. Maternal infections and smoking appeared more likely to result in confirmed or progressive hearing loss, whereas thyroid disease, diabetes, and hypertension were associated with transient abnormalities. These findings emphasize the importance of risk-stratified surveillance and highlight the role of maternal health optimization in reducing neonatal auditory morbidity.

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