Original Article

MEDICINE PALLIATIVE CARE

DOI: 10.47582/jompac.1766697

J Med Palliat Care. 2025;6(5):582-587

Hearing loss and associated risk factors in newborns with meconium aspiration syndrome: a single-center retrospective comparative cross-sectional study

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Cite this article as: Gülyüz A, Melekoğlu NA, Özdemir Y. Hearing loss and associated risk factors in newborns with meconium aspiration syndrome: a single-center retrospective comparative cross-sectional study. *J Med Palliat Care*. 2025;6(5):582-587.

Received: 15.08.2025 ◆ **Accepted**: 17.10.2025 ◆ **Published**: 24.10.2025

ABSTRACT

Aims: The aim of this study is to determine the prevalence of hearing loss in newborns diagnosed with meconium aspiration syndrome (MAS) and to evaluate potential risk factors.

Methods: A retrospective, comparative cross-sectional study was conducted between January 1, 2022, and December 31, 2024, at the Neonatal Intensive Care Unit of Malatya Training and Research Hospital. The study included 91 newborns diagnosed with MAS and 14.998 newborns in the control group. All cases were screened using automated auditory brainstem response (ABR) in accordance with the Joint Committee on Infant Hearing (2019) guidelines. Hearing loss was diagnosed based on clinical brainstem evoked response audiometry (BERA) at ≥60 dB HL. The groups were compared in terms of demographic, clinical, and treatment variables.

Results: The rate of permanent hearing loss was 2.17% (n=2) in the MAS group and 0.40% (n=60) in the control group. The difference was statistically significant (OR: 5.57; 95% CI: 1.31–23.61; p=0.054). The use of furosemide was higher in infants with hearing loss in the MAS group (OR: 28.67; p=0.086). No significant association was found between hyperbilirubinemia history and mechanical ventilation use and hearing loss.

Conclusion: The prevalence of hearing loss in newborns with MAS appeared higher than in the general population. However, the very small number of cases limits the statistical power of our study. These findings should therefore be interpreted as preliminary and hypothesis-generating. Hearing screening before discharge and careful use of ototoxic medications are recommended, while lifelong follow-up suggestions should be confirmed by larger prospective studies.

Keywords: Meconium aspiration syndrome, hearing loss, newborn, ototoxicity, ABR

INTRODUCTION

Meconium aspiration syndrome (MAS) is an important respiratory problem in the neonatal period resulting from the aspiration of meconium-containing amniotic fluid during or immediately after birth. Its incidence ranges from 0.04% to 0.2% in term and postterm infants and can lead to mortality and morbidity in severe cases.[1,2] Factors such as mechanical airway obstruction, chemical pneumonia, and pulmonary hypertension play a role in the pathophysiology of MAS.[3]

Treatment of MAS in neonatal intensive care units (NICUs) often includes mechanical ventilation, noninvasive ventilation, and oxygen support; in addition, broad-spectrum antibiotics such as aminoglycosides and diuretics such as furosemide may also be used.[4,5] However, some of these treatment approaches, particularly prolonged use of aminoglycosides, may have potential ototoxic effects on the hearing system.[6]

Neonatal hearing loss occurs in 1–3% of cases and, if not diagnosed and treated early, can adversely affect language, speech, and cognitive development.[7] It is thought that the risk of hearing loss may be increased in infants with MAS, depending on both the severity of the disease and the ototoxic drugs used during treatment.[8,9] Factors such as prolonged intensive care, high concentrations of oxygen support, and ventilator pressure levels may have adverse effects on cochlear function.[10]

The number of studies investigating the relationship between MAS and hearing loss is limited, and existing studies have generally been conducted with small sample sizes.[11,12] Therefore, determining the prevalence of hearing loss and associated risk factors in infants diagnosed with MAS is important for both the establishment of clinical follow-up protocols and the development of preventive strategies.

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The aim of this study is to determine the prevalence of hearing loss in newborns diagnosed with MAS and to evaluate potential risk factors. The hypothesis of our study is that the prevalence of hearing loss in infants with MAS is higher than in the general newborn population, and this finding is particularly pronounced in cases involving prolonged aminoglycoside use and ventilation support.[8,11-13]

METHODS

Ethics

Approval for the study was obtained from the Clinical Researches Ethics Committee of the Faculty of Medicine, Malatya Turgut Özal University (Date: 22.05.2025, Decision No: 2025/44). Since the study was conducted retrospectively and all data were anonymized, the requirement for individual informed consent was waived. The study was carried out in accordance with the principles of the Helsinki Declaration.

Study Design and Setting

This retrospective comparative cross-sectional study was conducted between January 1, 2022, and December 31, 2024, at the Neonatal Intensive Care Unit of Malatya Training and Research Hospital. The aim of the study was to determine the prevalence of hearing loss in newborns diagnosed with MAS and to compare this rate with a large control group consisting of the general newborn population.

Inclusion and Exclusion Criteria

Newborns were included in the MAS group if they were diagnosed with MAS based on clinical and radiological findings after birth, had undergone at least one automated auditory brainstem response (ABR) test during the neonatal period, and had complete records of all screening and advanced audiological evaluations. The control group consisted of infants who participated in the hospital's newborn hearing screening program between 2022 and 2024, had no diagnosis of MAS, and either passed the screening ABR test or had their hearing status confirmed through further brainstem evoked response audiometry (BERA). The control group could include infants with other high-risk factors such as prematurity or low birth weight, provided that MAS was absent. Infants were excluded from both groups if they had congenital ear malformations or craniofacial anomalies, diagnosed genetic syndromes (e.g., Down syndrome), a history of prenatal TORCH infections, middle ear pathology (e.g., effusion, acute otitis media), or incomplete medical records or hearing assessment data.

Sample and Groups

The MAS group included 91 newborns (44 female, 47 male) with a mean gestational age of 40.11±0.74 weeks and mean birth weight of 3319±439 g. The control group consisted of 14.998 newborns from the hospital newborn hearing screening database, among whom 60 had confirmed permanent hearing loss.

Data Collection

Clinical and demographic variables were obtained from the hospital automation system, newborn hearing screening unit records, and patient files. The variables included gender, gestational age, birth weight, mode of delivery (vaginal or cesarean), Apgar scores at 1 and 5 minutes, need for intubation and its duration, duration of mechanical and non-invasive ventilation, presence and treatment of hyperbilirubinemia, presence of sepsis confirmed by clinical and laboratory findings, use and duration of aminoglycosides (amikacin), and family history of hearing loss.

Hearing Assessment Protocol

All newborns underwent an initial automatic ABR test (Maico MB 11, Berlin, Germany) in a quiet environment while asleep during the first few days after birth. Cases that failed the screening test were re-evaluated within 1–2 weeks. Infants who failed the screening ABR test three times were referred for advanced clinical BERA testing at a reference center. Permanent sensorineural hearing loss (SNHL) was defined as a diagnostic ABR threshold >60 dB HL, corresponding to severe-to-profound hearing loss in the center's clinical protocol. Because individual records for the 40–60 dB HL range were not separately stored, cases with mild to moderate hearing loss could not be verified. All procedures were conducted according to the Joint Committee on Infant Hearing (2019) guidelines.

Statistical Analysis

The data analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean±standard deviation (SD) or median (minimum–maximum), and categorical variables as frequencies and percentages. The normality of distribution was assessed using the Shapiro–Wilk test. Comparisons of categorical variables were made using the Chi-square test, and Fisher's exact test (two-tailed) was applied when the expected cell count was less than 5. For the comparison of continuous variables, either the independent samples t-test or the Mann–Whitney U test was used, depending on the distribution. Odds ratios (OR) and 95% confidence intervals (CI) were calculated using 2×2 contingency tables to determine the relative risk of hearing loss. In addition, the E-value (VanderWeele) was calculated for both the OR and the lower limit of the 95% CI to evaluate the potential influence of unmeasured confounding. A p-value of <0.05 was considered statistically significant.

RESULTS

Demographic and Clinical Characteristics

Of the 91 newborns with MAS included in the study, 48.4% were female (n=44) and 51.6% were male (n=47). The mean gestational age was 40.11±0.74 weeks, and the mean birth weight was 3319±439 g. Of the 14.998 newborns in the control group, 50.0% were female (n=7.509). 50.0% were male (n=7489). In terms of mode of delivery, the cesarean section rate was 28.3% in the MAS group, while it was 18.9% in the control group, and this difference was statistically significant (p=0.022). Gestational age was significantly higher in the MAS group (p<0.001). There was no significant difference in birth weight between the two groups (p=0.291) (**Table 1**).

Table 1. Comparison of demographic and clinical characteristics between the MAS and control groups

Characteristic	MAS group	Control group	p
Gender (F/M)	44	7509	0.754
Mode of delivery (vaginal/cesarean)	65/26	12.168/2.830	0.022
Gestational week (mean±SD)	40.11±0.74	38.20±1.70	<0.001
Birth weight (g, mean±SD)	3319±439	3162±518	0.291
1-minute Apgar score*	6.21±1.06	No data	—
5-minute Apgar score*	7.82±0.83	No data	—

MAS: Meconium aspiration syndrome, Data are presented as mean±standard deviation (SD) or number (percentage). Categorical variables were compared using Fisher's exact test (two-tailed), and continuous variables were compared using an independent samples t-test. p<0.05 was considered statistically significant. Apgar data were not available for the control group

Prevalence of Hearing Loss

In the MAS group, 2 infants (2.17%) failed the newborn hearing screening test and were diagnosed with permanent hearing loss after further evaluation. In the control group, hearing loss was detected in 0.40% (n=60) of the infants. The prevalence of hearing loss in the MAS group was borderline statistically higher than in the control group (OR: 5.57; 95% CI: 1.31–23.61; Fisher two-tailed p=0.054). This value is just above the conventional threshold of statistical significance and should be interpreted with caution (Table 2).

Table 2. Prevalence of hearing loss in the MAS and control groups

Condition	MAS group	Control group	OR (95% CI)	p (Fisher two tailed)
Hearing loss	2 (2.17%)	60 (0.40%)	5.57 (1.31–23.61)	0.05 (borderline)

MAS: Meconium aspiration syndrome, OR: Odds ratio, CI: Confidence interval. Data are presented as mean±standard deviation (SD) or number (percentage). Categorical variables were compared using Fisher's exact test or Chi-square test, and continuous variables were compared using independent samples t-test. p<0.05 was considered statistically significant. p Fisher's exact test (two-tailed); OR and 95% CI calculated using the Wald approach.

The low number of cases of hearing loss in the MAS group (n=2) resulted in a wide CI (1.31–23.61) for the calculated OR value. This situation limits the statistical power of the study and indicates that the findings should be interpreted as "preliminary indicators" rather than "definitive results."

The E-value represents the minimum strength of association that an unmeasured confounder would need to fully explain away the observed relationship, and thus reflects the robustness of the results against hidden bias.

Subgroup Analysis of Hearing Loss Within the MAS Group

The univariate comparisons of 2 infants with hearing loss and 89 infants with normal hearing in the MAS group are presented in Table 3. Furosemide use was higher in infants with hearing loss (OR: 28.67), but this difference did not reach statistical significance (p=0.086). Given the very small number of cases (n=2), this result should be interpreted as exploratory. A history of hyperbilirubinemia was more common in infants with hearing loss but did not reach statistical significance (OR: 3.68; p=0.393). No significant differences were found in terms of gender, mode of delivery, birth weight, or gestational age (all p>0.05). Due to the very small number of cases with hearing loss (n=2), multivariate logistic regression analysis could not be performed. Therefore, the subgroup comparisons presented in Table 3 should be regarded as exploratory and hypothesis-generating rather than confirmatory results. Median (min–max) values were reported for continuous variables, and n (%) and Fisher Exact test p-values were reported for categorical variables.

The rate of sepsis confirmed by culture or clinical criteria in the MAS group was 18.7% (17/91). Neither of the infants with hearing loss had a history of sepsis.

Use of Mechanical Ventilation (MV) and Noninvasive Ventilation (NIMV)

Mechanical ventilation was applied to 24 (26.4%) of the 91 MAS patients in our study. Noninvasive ventilation (CPAP/NIMV) was applied to 67 patients (73.6%). Aminoglycoside use was present in all patients (100%), so no intergroup comparisons were made for this variable (Table 4).

Table 4. Relationship between mechanical and noninvasive ventilation and hearing loss

Variable	Hearing loss	Normal hearing	p
Mechanical ventilation	0 (0.0%)	24 (100.0%)	1.000
Non-invasive mechanical ventilation	2 (2.99%)	65 (97.01%)	1.000

Data are presented as numbers (percentages). Groups were compared using Fisher's exact test. Due to the very small number of cases, these comparisons have low statistical power and should be interpreted with caution. p<0.05 was considered statistically significant. "—" was used for values that could not be calculated in the OR column

Association with Hearing Loss

No hearing loss was observed in the group receiving mechanical ventilation (0/24). In the group receiving non-invasive mechanical ventilation (NIMV), hearing loss was detected in 2 infants (2.99%). No hearing loss was observed in the group that did not receive NIMV (0/24). This difference was not statistically significant (p=0.509, Fisher Exact test).

The data do not indicate a significant association between mechanical ventilation and hearing loss. Although all cases of

Table 3. Relationship between hearing loss and clinical and demographic variables

Variable	Hearing loss (n=2)	Normal hearing (n=89)	OR (95% CI)*	p
Furosemide use	1/2 (50.0%)	3/89 (3.4%)	28.6 (approx.)	0.086 (NS)
Hyperbilirubinemia	1/2 (50.0%)	14/89 (15.7%)	3.68	0.393
Cesarean delivery	0 (0.0%)	26 (29.2%)	0	1
Male	1 (50.0%)	47 (52.8%)	0.93	1
Birth weight, median (min–max)	3450 (3250–3650)	3325 (2200–4300)	—	0.732
Gestational age, median (min–max)	40.0 (40–40)	40.0 (38–42)	—	1.00

OR: Odds ratio, CI: Confidence interval, NS: Not significant, Min: Minimum, Max: Maximum. Data are presented as numbers (percentages). Groups were compared using Fisher's Exact test or the Chi-square test when appropriate. p<0.05 was considered statistically significant

hearing loss were observed in the group receiving noninvasive mechanical ventilation (n=2), the statistical power of this association is weak due to the small sample size. Further studies with larger sample sizes are needed.

DISCUSSION

This study investigated the prevalence of hearing loss in newborns diagnosed with MAS and potential associated factors, comparing them with a large control group. Our findings indicate that the rate of hearing loss in the MAS group (2.2%) was borderline higher than that in the control group (0.4%) (OR=5.57; Fisher two-tailed p=0.054). Given that this p-value is just above the traditional significance level, this result should be interpreted as suggestive rather than conclusive evidence. This finding, although suggestive, must be interpreted with great caution because of the very small number of cases and the limited statistical power of the study. Our results should be viewed as hypothesis-generating rather than definitive evidence. However, the small sample size (n=2) limited statistical power and highlighted the need to interpret the results as "preliminary" rather than "definitive."[14-16]

MAS is one of the major causes of neonatal morbidity and mortality and is commonly seen in term or postterm infants. Studies on the effect of MAS on neurosensory hearing loss are limited in the literature. For example, Borradori et al.[21] reported a 2.4% rate of permanent hearing loss in very low birth weight and preterm infants (n=2/85), which is similar to the 2.17% rate in our study. Smith et al.[22] found a 3% rate of hearing loss in 100 MAS cases. These similar rates indicate that the prevalence of hearing loss in MAS cases is within a narrow range across different centers with similar sample sizes. Coenraad et al.[23] demonstrated that the combination of aminoglycoside and furosemide exposure with hypoxia significantly increased the risk of hearing loss in newborn intensive care patients.

In our study, the use of furosemide was higher in infants with hearing loss (OR=28.67), but this did not reach statistical significance (p=0.086) and should be interpreted as an exploratory observation. Similarly, because aminoglycoside exposure was universal in the MAS group, its independent effect on hearing loss could not be assessed. These findings are descriptive and should not be considered definitive evidence of causality. The ototoxic potential of furosemide has been demonstrated in numerous previous studies. Although hyperbilirubinemia is a known risk factor for hearing loss, no significant association was found in our study; this may be explained by the fact that bilirubin levels were controlled with treatment in most cases and by sample inadequacy. No significant association was found between the use of mechanical and noninvasive ventilation and hearing loss. This discrepancy suggests that the findings reported in the literature regarding the potential risk associated with prolonged ventilation may be related to sample size.[15,18,19]

Low Apgar scores, especially below 7 at 1 and 5 minutes, are an indirect indicator of perinatal asphyxia and hypoxic-ischemic injury in newborns. Hypoxia can cause irreversible damage to the hair cells of the cochlea, which have high metabolic energy requirements. Previous studies have reported a significant association between low Apgar scores and hearing loss in newborns.

Since Apgar data for the control group were not available, no comparison between groups could be made. The mean Apgar scores at 1 and 5 minutes in the MAS group were similar to those reported in the literature for term MAS cases. These values support the notion that the presence of meconium at birth is often associated with moderate perinatal stress.[16,20,24]

Strengths and Limitations of the Study

Strengths include the use of a standardized hearing screening protocol at a single center and the inclusion of a large control group. Limitations include the small number of hearing loss cases, the inability to establish a causal relationship due to the retrospective comparative cross-sectional design, and the use of data from a single center.[18,21-22]

Individual data on gestational age and/or birth weight are not available in the control group; this may have led to the inclusion of preterm and low birth weight infants in the control group. Since these factors increase the risk of hearing loss, such a distribution is likely to introduce a bias toward null rather than exaggerating the comparison. However, the inclusion of these higher-risk infants may still have affected our results and should be considered an important limitation when interpreting the findings. For the 95% GA lower limit, the E-value=1.95, suggesting that the relationship cannot be fully explained by an unmeasured confounder that is approximately twice as associated with both variables. However, this data deficiency is an important limitation of the study. The small number of outcome events (n=2) severely limits the precision of risk estimates and may lead to type II error.

The use of the ≥60 dB HL threshold may have resulted in mild-moderate (40–60 dB HL) cases not being classified as 'permanent,' leading to a lower reported number of cases; this creates a conservative effect that shifts the findings toward null. For future studies, diagnostic data stratified by severity and sensitivity analyses at ≥40 dB HL are recommended.

Although the potential ototoxic effects of aminoglycosides are well-documented in the literature, the independent effect of this factor could not be assessed in our study due to the use of aminoglycosides in all infants in the MAS group.

Detailed prenatal and postnatal clinical data could not be completely retrieved for the control group. Minor variations existed in the timing and method of hearing screening tests. Duration and serum levels of aminoglycoside exposure were not comparable between groups. Because of the retrospective design, all potential confounders could not be fully controlled.

Clinical Implications and Recommendations

Our results indicate that the risk of hearing loss in newborns with MAS is higher than in the general population. Therefore, it is important not to omit hearing screening in MAS cases, to use ototoxic medications with caution, and to maintain ventilation parameters at low risk levels. According to the 2019 JCIH guidelines, hearing screening should be performed completely before discharge in high-risk infants, and if

risk factors are present, they should be followed up with advanced audiological evaluation within the first 9 months. Additionally, the importance of lifelong hearing follow-up in high-risk infants should be emphasized in accordance with the 2021 WHO recommendations.[24]

From a clinical perspective, these findings emphasize the importance of performing careful hearing screening before discharge in newborns diagnosed with MAS. Furthermore, strict monitoring of aminoglycoside dosage and duration during treatment may help detect and prevent potential ototoxic effects at an early stage. Such measures could contribute to reducing the risk of long-term auditory sequelae in vulnerable infants.

CONCLUSION

This study suggests that the prevalence of hearing loss in newborns diagnosed with MAS may be higher than in the general newborn population. However, because only two cases of hearing loss were observed, the statistical power is very limited, and these findings should be considered preliminary and hypothesis-generating rather than definitive.

Our results support the importance of performing complete hearing screening before discharge and using ototoxic medications with caution in MAS cases. Nevertheless, recommendations such as lifelong hearing follow-up cannot be made definitively based on our limited data and should be verified by larger multicenter prospective studies.

Further research with larger sample sizes is needed to better clarify the association between MAS and hearing loss and to guide evidence-based follow-up protocols.

ETHICAL DECLARATIONS

Ethics Committee Approval

Approval for the study was obtained from the Clinical Researches Ethics Committee of the Faculty of Medicine, Malatya Turgut Özal University (Date: 22.05.2025, Decision No: 2025/44).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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