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Critical Review or Scoping Review

A survey of strategies for the early diagnosis of hearing loss in infants: a scoping review

Um levantamento das estratégias para o diagnóstico precoce da perda auditiva em lactentes: uma revisão de escopo

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Keywords

Neonatal Screening
Hearing Loss
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ABSTRACT

Purpose: To map the strategies used for the early diagnosis of hearing loss in infants. **Research strategies:** A comprehensive literature search was conducted in PubMed/MEDLINE, Scopus, Embase, Web of Science, LILACS, Google Scholar, and ProQuest, with no restrictions on language or publication period. The search was initially performed in October 2024 and updated in January 2026. Controlled descriptors (DeCS/MeSH) and keywords related to hearing loss, newborn hearing screening, and early diagnosis were used. The protocol was registered in the Open Science Framework. **Selection criteria:** Primary studies addressing strategies for the early diagnosis of hearing loss in children up to two years of age were included. Secondary studies, case reports, guidelines, duplicate publications, and studies without full-text availability were excluded. Study selection was performed independently by reviewers, with disagreements resolved by consensus. **Data analysis:** Extracted data included study design, population, diagnostic instruments, strategies, and care setting. A descriptive and narrative synthesis was conducted, grouping evidence according to diagnostic approaches. **Results:** Of the 16,946 records identified, 58 studies published between 1991 and 2025 met the eligibility criteria. Universal Newborn Hearing Screening (UNHS) predominated, particularly protocols combining otoacoustic emissions and automated auditory brainstem response. Complementary strategies included two-stage screening, early retesting, community-based programs, genetic screening, and additional electrophysiological assessments. Variability in protocol implementation and persistent structural inequalities were observed. **Conclusion:** UNHS remains the cornerstone of early diagnosis of hearing loss in infants, with effectiveness dependent on well-organized care pathways and integration between screening, diagnosis, and follow-up.

Descritores

Triagem Neonatal
Perda Auditiva
Bebê
Diagnóstico Precoce
Revisão de Escopo

RESUMO

Objetivo: Mapear as estratégias utilizadas para o diagnóstico precoce da perda auditiva em lactentes. **Estratégia de pesquisa:** A busca bibliográfica foi realizada nas bases PubMed/Medline, Scopus, Embase, Web of Science, LILACS, Google Scholar e ProQuest, sem restrição de idioma ou período de publicação, inicialmente realizada em outubro de 2024 e atualizada em janeiro de 2026. Utilizados descritores controlados (DeCS/MeSH) e palavras-chave relacionados à perda auditiva, triagem auditiva neonatal e diagnóstico precoce. O protocolo foi registrado na Open Science Framework. **Critérios de seleção:** Foram incluídos estudos primários que abordaram estratégias de diagnóstico precoce da deficiência auditiva em crianças de até dois anos. Excluíram-se estudos secundários, relatos de caso, diretrizes, artigos duplicados ou sem texto completo. A seleção foi realizada por revisores independentes, com consenso em caso de divergência. **Análise dos dados:** As informações extraídas abrangeram delineamento, população, instrumentos utilizados, estratégias diagnósticas e contexto assistencial. A síntese foi descritiva e narrativa, com agrupamento das evidências por tipo de abordagem. **Resultados:** Dos 16.946 registros identificados, 58 estudos, publicados entre 1991 e 2025, atenderam aos critérios de elegibilidade. Predominaram estratégias baseadas na Triagem Auditiva Neonatal Universal (TANU), com associação entre emissões otoacústicas e potencial evocado auditivo de tronco encefálico automatizado. Estratégias complementares incluíram protocolos em dois estágios, reteste precoce, programas comunitários, triagem genética e exames eletrofisiológicos adicionais. Observou-se variabilidade na operacionalização dos protocolos e persistência de desigualdades estruturais. **Conclusão:** A TANU permanece como eixo central do diagnóstico precoce da perda auditiva em lactentes, com efetividade dependente da organização dos fluxos assistenciais e da integração entre triagem, diagnóstico e acompanhamento.

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INTRODUCTION

Hearing plays a central role in child development and is directly related to language acquisition, communication, and cognitive and social skills[1,2]. Hearing deprivation during the first years of life may lead to long-term educational, emotional, and social impairments, making early identification and intervention essential to mitigate these impacts[1-3].

In this context, Universal Newborn Hearing Screening (UNHS) programs have become an important public health policy in several countries, aiming to promote the early detection of hearing loss[4,5]. However, structural, organizational, and contextual challenges—more prominently highlighted during the COVID-19 pandemic—have compromised the continuity of these programs, resulting in delays in diagnosis, intervention, and follow-up care[5-7].

National and international guidelines recommend the combined use of Otoacoustic Emissions (OAE) and Automated Auditory Brainstem Response (AABR) as the gold-standard protocol for newborn hearing screening, preferably to be performed within the first 48 hours of life or up to 30 days after birth[2,6,8-10]. However, the existence of formal recommendations does not ensure their homogeneous implementation in clinical practice. Differences among healthcare systems, between public and private sectors, as well as failures in the integration of healthcare networks, result in variations in diagnostic pathways and in the effectiveness of follow-up care[8-11].

The literature suggests that strategies for the early diagnosis of hearing loss in infants remain fragmented, often focusing on specific technologies or populations without comprehensively considering organizational, socioeconomic, and geographic factors that influence access to services and continuity of care[8,12-14]. This heterogeneity hinders comparisons across contexts and limits the identification of patterns that could support the improvement of clinical practices and public hearing health policies[9,13,15].

Given the epidemiological relevance of childhood hearing loss and the persistent challenges related to its early detection and intervention[12,13,16-19], a gap remains in the literature regarding a critical synthesis of the strategies employed for early diagnosis, encompassing not only the tests used but also care pathways, protocols, educational interventions, and health policies. Therefore, the objective of this scoping review was to map the strategies used for the early diagnosis of hearing loss in infants by gathering and synthesizing the available scientific evidence in order to contribute to the improvement of clinical practices and the strengthening of public policies for child hearing health.

METHODS

This scoping review was conducted in accordance with the methodological recommendations of the Joanna Briggs Institute (JBI)[20] and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) checklist[21]. The study protocol was previously registered on the Open Science Framework (OSF)[22].

Eligibility criteria

The research question was formulated based on the PCC strategy (Population, Concept, and Context), defined as follows:

P – infants (0–2 years);

C – strategies used for the early diagnosis of hearing loss;

C – hearing healthcare services and settings.

Thus, the guiding research question was: "What strategies have been used for the early diagnosis of hearing loss in infants?"

Inclusion criteria

Studies addressing strategies, protocols, programs, or methods applied to the early diagnosis of hearing impairment in children up to two years of age were included, as were primary studies, including cross-sectional observational, cohort, case-control, quasi-experimental, experimental, and methodological studies. No restrictions regarding language or publication date were applied.

Gray literature (theses, dissertations, institutional documents, and technical reports) was excluded in order to ensure greater reproducibility, methodological standardization, and data comparability, prioritizing studies published in peer-reviewed scientific journals.

Exclusion criteria

Studies involving participants outside the proposed age range, studies that did not meet the predefined inclusion criteria, studies that did not address specific strategies for the assessment or diagnosis of hearing loss, or studies that did not specify the age at detection were excluded. Secondary studies (systematic, narrative, and integrative reviews, as well as meta-analyses), clinical guidelines, case reports, case series, opinion articles, technical texts, books, websites, blogs, and other non-scientific sources were also excluded. Articles whose full texts could not be obtained, even after contacting the authors, were likewise excluded.

Search strategy

The bibliographic search was initially conducted in the PubMed/MEDLINE database and subsequently adapted for the following databases: Embase, Scopus, Web of Science, LILACS, Google Scholar, and ProQuest. The search was performed on October 15, 2024, and updated on January 5, 2026 (Appendix A). In Google Scholar, the first 200 references sorted by relevance were screened, in accordance with methodological recommendations for scoping reviews.

The search strategy was adapted to each database and combined controlled and uncontrolled descriptors (MeSH, DeCS, and free keywords) related to the main study concepts, using the Boolean operators AND and OR, as well as truncation and spelling variations, according to the specificities of each database.

Reference management and screening

The search results were initially exported to Zotero software (version 7.0), which was used exclusively for reference organization and automatic duplicate removal. Subsequently, the records were imported into the Rayyan platform[23] where an additional manual duplicate check was performed to increase the accuracy of the process, followed by title and abstract screening.

Before the selection process began, the reviewers participated in a calibration stage involving the joint analysis of a pilot sample of studies in order to standardize the application of the eligibility criteria.

Study selection

Study selection was carried out in two stages. In the first stage, titles and abstracts were independently assessed by six reviewers organized into three pairs (pair 1: ADSL and SAS; pair 2: APCF and ROF; pair 3: MCOA and MHM). The division into three pairs aimed to distribute the volume of records evenly, ensuring greater efficiency and rigor during the initial screening process.

Each database was reviewed by at least one pair of reviewers, ensuring the uniform application of the eligibility criteria. In the second stage, the full texts of potentially eligible studies were independently assessed by the same reviewers.

Decisions were initially made by consensus within each pair. In cases of disagreement, the study was discussed in meetings involving all reviewer pairs. If disagreement persisted, a third independent reviewer was consulted for the final decision. Throughout all stages, reviewers remained blinded to the decisions of the other reviewer pairs, according to the functionality provided by the Rayyan platform.

Data extraction and analysis

Data were extracted using a structured form developed by the authors, including: (a) study identification (authors, year, country, language, and type of publication); (b) methodological characteristics (study design, sample, instruments used, and target population); (c) description of the applied early diagnosis strategies; and (d) main findings and conclusions.

The results were synthesized descriptively and narratively, with presentation in tables and figures grouping the identified strategies according to the type of approach (technological, clinical, educational, or policy-related). Whenever applicable, knowledge gaps and recommendations for future research in the field of child hearing health were highlighted.

RESULTS

The study search and selection process is presented in the PRISMA-ScR flowchart (Figure 1). A total of 16,946 records were initially identified across the searched databases. After duplicate removal and title and abstract screening, 413 articles were selected for full-text review, of which 355 were excluded (Appendix B). Consequently, 58 studies met the eligibility criteria and comprised the final sample. Most exclusions were due to the absence of a focus on early diagnosis, inclusion of age groups older than two years, or the use of study designs incompatible with the scope of this review.

The general characteristics of the included studies are presented in Table 1. Publications ranged from 1991 to 2025, with a marked increase after 2015 (n = 20)[64-83]. The temporal distribution of publications is shown in Figure 2.

Regarding geographic distribution, studies conducted in North America, Europe, and Asia predominated, particularly those from the United States[31,33,39,40,68,70,80], India[58,59,69,72,74,78,81], China[49,54,60,63], and Türkiye[43,46,55,62]. Figure 3 presents the geographic distribution of the included studies. Few publications originated from Latin America (n = 3)[41,45,77] and Africa (n = 4)[44,51,79,82].

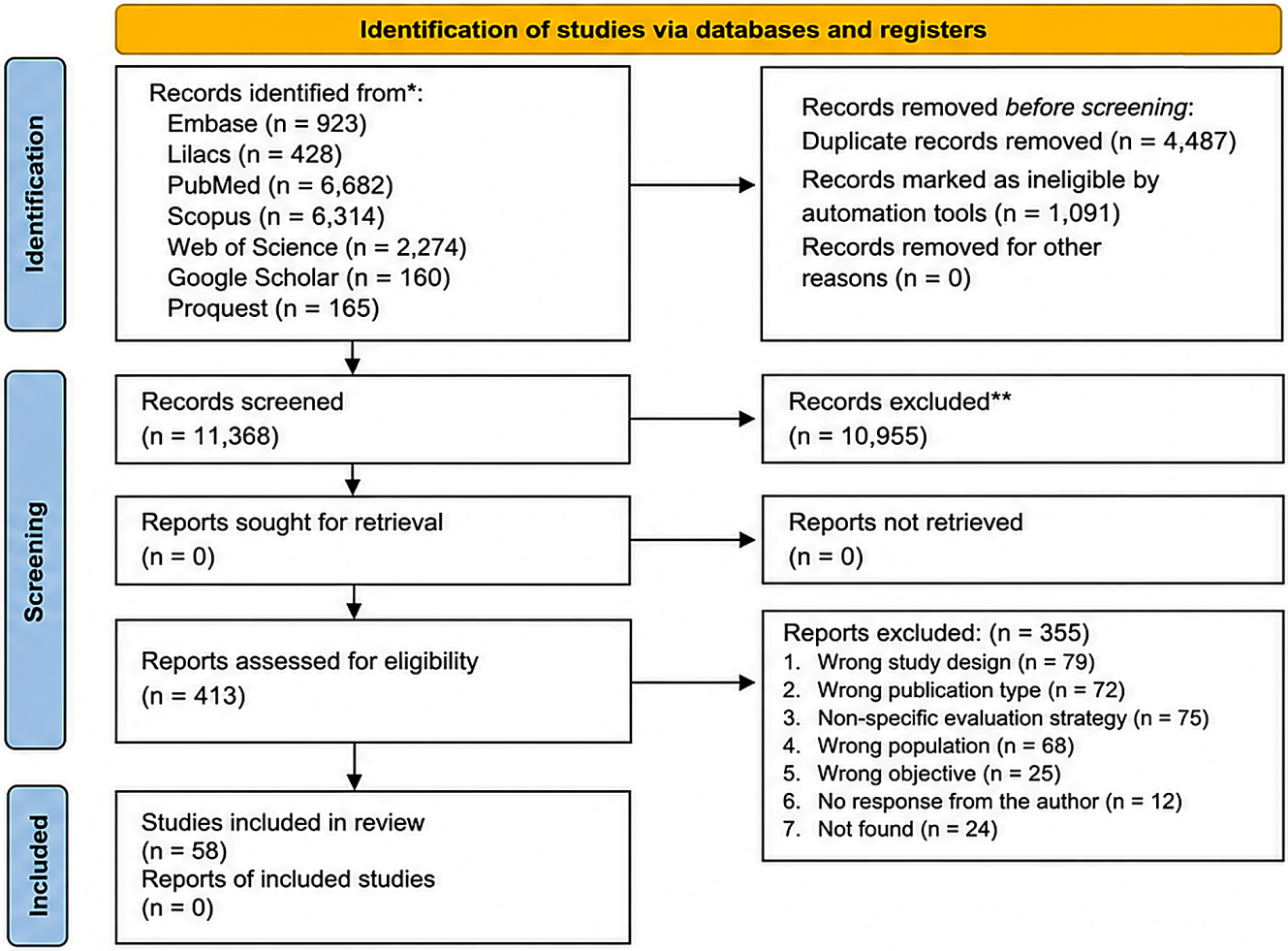
Descriptive observational studies, mainly cross-sectional and retrospective in design, predominated and accounted for most of the sample (n = 35). These studies were primarily linked to Universal Newborn Hearing Screening (UNHS) programs or referral hospital services. Prospective cohort studies and clinical trials were less frequent (n = 18) and mainly aimed at evaluating diagnostic accuracy and validating combined protocols. Sample sizes varied considerably, ranging from 50[58] to 179,000[66] participants, demonstrating substantial heterogeneity among the included studies.

The identified strategies for the early diagnosis of childhood hearing loss predominantly involved universal newborn hearing screening, with the use of otoacoustic emissions (TEOAE/DPOAE) reported in 89.6% of the studies (n = 52), auditory brainstem response (ABR) in 77.5% (n = 45), and automated ABR (AABR) in 41.3% (n = 24). Two-stage protocols, generally consisting of OAE followed by AABR, were described in approximately 35% of the studies (n = 20).

Complementary strategies were also identified, including approaches directed toward at-risk populations (n = 7)[26,28,46,53,68,69,74,78], parental education and counseling interventions (n = 2)[68,72], expanded electrophysiological test batteries (n = 7)[38,41,56,58,70-72], and behavioral assessments (n = 9)[27,30,34,37,42,47,58,77,81]. To a lesser extent, some studies reported the incorporation of complementary etiological testing, such as genetic screening associated with neonatal hearing assessment (n = 1)[54].

Regarding healthcare settings, most studies were conducted in maternity wards and public hospitals (n = 52), whereas initiatives developed in primary healthcare or community services were less frequent (n = 6)[35,47,51,53,65,79]. The main reported barriers included loss to follow-up during retesting, communication failures between maternity hospitals and specialized services, lack of equipment availability, and logistical difficulties related to access to healthcare services[31,34,47,52,60,66,77]. In contrast, studies reporting better healthcare indicators described the adoption of universal two-stage protocols, active family follow-up strategies, computerized case-monitoring systems, and structured parental education programs[39,43,48,55,56,58,61,67,72,73,82].

Based on the synthesis of the included studies, a summary figure (Figure 4) was developed integrating diagnostic strategies, healthcare settings, and recurrent barriers related to the early diagnosis of childhood hearing loss.



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers);
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools

Figure 1. Flow diagram according to the PRISMA-ScR guidelines[25] (adapted)

Table 1. Characteristics of the studies included in the review

	Authors (Year)	Methodological Characteristics		Procedures	Outcomes
		Study Design	Sample		
1	Webb and Stevens (1991)[26]	Comparative	250	TEOAE / ABR	Newborn hearing screening should begin with TEOAE due to its efficiency and cost-effectiveness. ABR should be used for diagnostic confirmation and differentiation of hearing loss type.
2	Tudehope et al. (1992)[27]	Prospective	149	ABR / BOA / Immittance	Early auditory assessment in very low birth weight neonates is essential for identifying hearing loss, particularly conductive loss. The combination of ABR, behavioral audiometry, and immittance measures provides a comprehensive diagnostic approach.
3	Morlet et al. (1998)[28]	Prospective	1.531	TEOAE / ABR	The screening process successfully identified hearing loss in a high-risk population, highlighting the need for repeated assessments during the first year of life for children with initially abnormal results.
4	Aidan et al. (1999)[29]	Cohort	1.727	TEOAE	The study demonstrated the feasibility and limitations of TEOAE as a universal newborn hearing screening tool.

Caption: BOA = Behavioral Observation Audiometry; AABR = Automated Auditory Brainstem Response; ABR = Auditory Brainstem Response; ASSR = Auditory Steady-State Response; DPOAE = Distortion Product Otoacoustic Emissions; Immittance = Immittance Measures; TEOAE = Transient Evoked Otoacoustic Emissions; Tympanometry = Tympanometry; VRA = Visual Reinforcement Audiometry
Source: Page et al.[24]

Table 1. Continued...

	Authors (Year)	Methodological Characteristics		Procedures	Outcomes
		Study Design	Sample		
5	Watkin and Baldwin (1999)[30]	Retrospective	100	TEOAE / ABR / BOA	Newborn hearing screening is effective for early identification of hearing impairment; however, adequate follow-up and effective parental communication are essential to confirm diagnosis and initiate early intervention.
6	Prieve et al. (2000)[31]	Prospective	43.311	TEOAE / AABR / ABR	Outpatient indicators improved over time, with significant differences between neonates admitted to the NICU and those from routine nurseries, in addition to regional disparities requiring further investigation.
7	Shehata-Dieler et al. (2000)[32]	Prospective	1.349	ABR / OAE	The BeRapHon® method proved to be an effective and highly specific tool for universal newborn hearing screening.
8	Stewart et al. (2000)[33]	Prospective	11.711	AABR / ABR / Tympanometry / TEOAE	Universal hearing screening using AABR proved highly effective and feasible across different hospitals, with low follow-up costs and minimal interference in parent–infant bonding.
9	Baumann and Schorn (2001)[34]	Cohort	102	TEOAE / BOA / ABR	Behavioral band testing was inadequate for hearing screening, detecting only 61.5% of cases. In contrast, otoacoustic emissions testing effectively identified hearing loss, and automated devices such as Echoscreen demonstrated high specificity.
10	Owen et al. (2001)[35]	Prospective	683	OAE	Community-based newborn hearing screening conducted by healthcare workers was feasible, well accepted, and associated with high population coverage and low false-positive rates.
11	Lin et al. (2002)[36]	Prospective	6.765	TEOAE / ABR	The use of TEOAE as a universal newborn hearing screening tool was feasible, accurate, and cost-effective.
12	Iwasaki et al. (2003)[37]	Prospective	4.085	AABR / ABR / OAE / BOA	A two-stage AABR screening protocol effectively reduced referral and false-positive rates among newborns.
13	Rouev et al. (2004)[38]	Prospective	1.838	AABR / ABR	Universal newborn hearing screening in Bulgaria using a two-stage protocol with AABR and ABR proved effective and cost-effective for early hearing loss detection, despite challenges related to follow-up of referred cases.
14	White et al. (2005)[39]	Prospective	86.634	OAE / AABR	The newborn hearing screening protocol using OAE and AABR identified most infants with permanent hearing loss; however, a substantial proportion would have passed the AABR screening.
15	Widen et al. (2005)[40]	Prospective	973	OAE / AABR / VRA	Newborn hearing screening should include continuous monitoring beyond the neonatal period. VRA was appropriate for most infants, although examiner experience influenced diagnostic effectiveness.
16	Yee-Arellano et al. (2006)[41]	Prospective	3.066	AABR / ABR	Even with a reduced pilot sample, the rates of identified hearing loss were similar to those reported in other countries. The study highlighted the feasibility of the program and the need for expansion, emphasizing operational and follow-up aspects.
17	De Capua et al. (2007)[42]	Prospective	19.700	OAE / ABR / BOA	Diagnostic ABR was preferable to automated ABR due to its greater diagnostic accuracy.
18	Tatli et al. (2007)[43]	Prospective	711	TEOAE / ABR	A two-stage TEOAE newborn hearing screening program was feasible and well accepted by families. Effective screening was achieved in 96% of neonates admitted to the nursery.

Caption: BOA = Behavioral Observation Audiometry; AABR = Automated Auditory Brainstem Response; ABR = Auditory Brainstem Response; ASSR = Auditory Steady-State Response; DPOAE = Distortion Product Otoacoustic Emissions; Immittance = Immittance Measures; TEOAE = Transient Evoked Otoacoustic Emissions; Tympanometry = Tympanometry; VRA = Visual Reinforcement Audiometry
Source: Page et al.[24]

Table 1. Continued...

	Authors (Year)	Methodological Characteristics		Procedures	Outcomes
		Study Design	Sample		
19	Olusanya et al. (2008)[44]	Cross-sectional	1.330	TEOAE / ABR	Hospital-based universal newborn hearing screening was feasible in urban Nigerian settings, even when conducted by non-specialized personnel after brief training, showing effective detection and low referral rates.
20	Dantas et al. (2009)[45]	Retrospective	1.626	TEOAE	The findings reinforced the importance of implementing and maintaining newborn hearing screening programs and may support comparisons in regional and multinational studies.
21	Ohl et al. (2009)[46]	Retrospective	1.461	Automated OAE / OAE / ABR	The screening program for high-risk infants enabled early management of 60 deaf children, although loss to follow-up after screening remained substantial.
22	Geal-Dor et al. (2010)[47]	Comparative	1.545	TEOAE / BOA	Newborn hearing screening using TEOAE was objective and favored early detection and adherence. Subsequent behavioral screening was useful for identifying late-onset or progressive hearing deficits, including auditory neuropathy. Both methods were complementary rather than interchangeable.
23	Tasci et al. (2010)[48]	Retrospective	16.975	TEOAE / ABR	The three-stage protocol was accurate and noninvasive; however, reorganization into a two-stage approach (initial TEOAE followed by ABR) was suggested to improve coverage.
24	Yu et al. (2010)[49]	Retrospective	6.336	DPOAE / AABR	The combined DPOAE and AABR screening protocol proved feasible and more efficient for newborn hearing screening.
25	Daniel and Lim (2012)[50]	Retrospective	100.237	OAE / AABR / ABR	The newborn hearing screening program in Singapore was effective for early identification of hearing impairment and provided opportunities for timely intervention.
26	Friderichs et al. (2012)[51]	Cross-sectional	6.227	DPOAE	Low screening coverage highlighted the need for dedicated personnel, rather than regular clinic staff, to achieve broader and more effective screening rates.
27	Lim et al. (2012)[52]	Retrospective	10.879	AABR / ABR / Tympanometry	The AABR screening protocol demonstrated acceptable referral rates and predictive values.
28	Martines et al. (2012)[53]	Comparative	412	TEOAE / Tympanometry / ABR	A high prevalence of auditory neuropathy spectrum disorder was identified among high-risk infants. Family history and NICU admission were independent predictors. Combined screening (TEOAE + ABR) demonstrated better performance than isolated TEOAE, especially for detecting auditory neuropathy in high-risk neonates.
29	Zhang et al. (2012)[54]	Prospective	10.043	DPOAE / AABR / Genetic screening	Combined hearing and genetic screening improved identification of newborns at risk for hearing loss, including cases associated with recessive mutations or drug-induced hearing impairment.
30	Arslan et al. (2013)[55]	Prospective	2.229	Automated TEOAE / AABR	Automated TEOAE proved feasible for newborn hearing screening, and the two-stage protocol effectively reduced false-positive referral rates.
31	Borkoski Barreiro et al. (2013)[56]	Retrospective	26.717	Automated TEOAE / TEOAE / ABR / ASSR	The early hearing detection program achieved coverage above 95%, although referral rates for diagnostic confirmation remained below recommended levels. Nevertheless, the protocol proved suitable for hospital routine and ensured substantial screening coverage.
32	Hsu et al. (2013)[57]	Prospective	3.361	TEOAE / AABR	The universal newborn hearing screening program using AABR demonstrated high coverage and low referral rates.

Caption: BOA = Behavioral Observation Audiometry; AABR = Automated Auditory Brainstem Response; ABR = Auditory Brainstem Response; ASSR = Auditory Steady-State Response; DPOAE = Distortion Product Otoacoustic Emissions; Immittance = Immittance Measures; TEOAE = Transient Evoked Otoacoustic Emissions; Tympanometry = Tympanometry; VRA = Visual Reinforcement Audiometry
Source: Page et al.[24]

Table 1. Continued...

	Authors (Year)	Methodological Characteristics		Procedures	Outcomes
		Study Design	Sample		
33	Kuki et al. (2013)[58]	Comparative	50	BOA / TEOAE / AABR / ABR / ASSR	Combining BOA with TEOAE and/or AABR enabled accurate, cost-effective, and well-accepted hearing screening. Due to its simplicity, low cost, and acceptability, BOA may be especially useful in low-resource settings where universal screening is not yet implemented.
34	Mishra et al. (2013)[59]	Prospective	1.101	DPOAE / ABR	The combination of DPOAE and ABR was effective for universal newborn hearing screening and early detection of hearing loss in children younger than 2 years.
35	Qi et al. (2013)[60]	Prospective	10.983	TEOAE / ABR	High screening coverage and reduced referral rates were feasible and practical among newborns of migrant workers.
36	Amini et al. (2014)[61]	Case series	149	TEOAE / Tympanometry / ABR	A significant association was observed between low birth weight and abnormal otoacoustic emissions. Altered OAE responses were identified in 2% of asphyxiated newborns.
37	Çelik et al. (2014)[62]	Retrospective	142.128	TEOAE / ABR	Hearing screening proved essential for all newborns to support developmental outcomes. Infants with risk factors required repeated testing for early diagnosis, and improvements in prenatal care could contribute to reducing hearing impairment rates.
38	Huang et al. (2014)[63]	Prospective	13.315	TEOAE / AABR / ABR	The combination of TEOAE and AABR followed by complete audiological assessment constituted an effective universal newborn hearing screening model for high-risk infants admitted to the NICU.
39	Canet et al. (2016)[64]	Retrospective	14.247	OAE / ABR	The screening program proved useful; however, improvements in tracking and follow-up processes were necessary. Effectiveness was limited by loss to follow-up, reinforcing the importance of electronic records and coordinated care.
40	Chrobok et al. (2019)[65]	Descriptive	—	OAE / ABR	Newborn hearing screening techniques (TEOAE and ABR) were effective, objective, and rapid. Universal implementation was considered essential for early identification of hearing loss and intervention before six months of age.
41	Wasser et al. (2019)[66]	Prospective	179.000	TEOAE / ABR	The national newborn hearing screening program in Israel achieved high coverage and significantly reduced the age at diagnosis and habilitation among infants with hearing loss.
42	Dey et al. (2020)[67]	Prospective	264	DPOAE / ABR	Hearing impairment was associated with hyperbilirubinemia requiring phototherapy or exchange transfusion, suggesting its role as a predictive indicator for hearing loss development.
43	McInerney et al. (2020)[68]	Retrospective	604	DPOAE / ABR	The findings highlighted the need to address barriers associated with loss to follow-up and recommended the use of strategies to improve parental engagement.
44	Nishad et al. (2020)[69]	Prospective	1.000	TEOAE / ABR	A well-structured protocol including initial OAE screening and ABR retesting was necessary for early hearing loss detection. Higher incidence rates were observed among high-risk neonates. OAE was useful for rapid screening, whereas ABR remained essential for definitive diagnosis.
45	Kelly et al. (2021)[70]	Retrospective	31.984	ABR	Delaying ABR testing to approximately 10–11 hours after vaginal delivery and 30–32 hours after cesarean delivery significantly improved pass rates. Inclusion of a third post-discharge test further reduced referral rates.

Caption: BOA = Behavioral Observation Audiometry; AABR = Automated Auditory Brainstem Response; ABR = Auditory Brainstem Response; ASSR = Auditory Steady-State Response; DPOAE = Distortion Product Otoacoustic Emissions; Immittance = Immittance Measures; TEOAE = Transient Evoked Otoacoustic Emissions; Tympanometry = Tympanometry; VRA = Visual Reinforcement Audiometry
Source: Page et al.[24]

Table 1. Continued...

	Authors (Year)	Methodological Characteristics		Procedures	Outcomes
		Study Design	Sample		
46	Shim et al. (2021)[71]	Retrospective	3.059	AABR / ABR / Tympanometry / ASSR / TEOAE	The two-stage AABR screening protocol demonstrated effective performance within JCIH-recommended referral rates (3–4%). The study validated this method as appropriate for hospital-based newborn hearing screening.
47	Arora et al. (2022)[72]	Prospective	1.200	TEOAE / ABR / ASSR	Newborn hearing screening was feasible in low-resource settings, particularly when associated with community programs and parental education strategies.
48	Gharibi and Khavidaki (2022)[73]	Cross-sectional	7.700	TEOAE / AABR / ABR	A comprehensive newborn hearing screening program was essential to ensure timely diagnosis and treatment, with early identification and intervention being decisive for effective auditory rehabilitation.
49	Hajare and Mudhol (2022)[74]	Comparative	800	DPOAE / AABR / ABR	A centralized screening facility could benefit hospitals lacking resources for universal or high-risk hearing screening programs.
50	Khaimook et al. (2022)[75]	Retrospective	1.579	OAE / ABR / Tympanometry	The universal newborn hearing screening program was effective in early identification and referral of children with hearing loss, highlighting family support and interdisciplinary care as key factors for improved outcomes.
51	Mazlan et al. (2022)[76]	Retrospective	50.569	TEOAE / AABR / ABR	The program achieved excellent screening coverage; however, performance remained below expectations regarding referral, follow-up, and diagnostic confirmation. Program revision and optimization were recommended to maintain effectiveness and relevance.
52	Dutra et al. (2023)[77]	Cross-sectional	104	TEOAE / VRA / BOA / ABR / ASSR	Limited access to hearing healthcare services delayed diagnostic confirmation and intervention. Maternal age, education, and distance from healthcare services did not significantly influence service utilization.
53	Badusha et al. (2024)[78]	Prospective	117	DPOAE / ABR	The high incidence of hearing impairment among high-risk infants reinforced the importance of newborn hearing screening. Collaboration between healthcare professionals and parents was essential for effective screening and intervention.
54	Kgare and Joubert (2024)[79]	Retrospective	2.302	Tympanometry / ABR / ASSR	Community-based universal newborn hearing screening proved feasible in a rural setting; however, high loss-to-follow-up rates and delayed screening age compromised the effectiveness of early diagnosis.
55	Jennings and Isaacson (2025)[80]	Retrospective	2.069	TEOAE / AABR	Although newborn hearing screening before hospital discharge achieved high coverage, early diagnostic effectiveness was compromised by outpatient loss to follow-up (43%) and socioeconomic barriers such as transportation, insurance, and childcare responsibilities.
56	Chandrakapure et al. (2025)[81]	Retrospective	28.025	BOA / TEOAE / AABR / ABR	Universal newborn hearing screening conducted at a tertiary healthcare center achieved high coverage and excellent diagnostic performance; however, poor adherence to post-screening follow-up limited the effectiveness of early diagnosis.
57	Ndoleriire et al. (2025)[82]	Cross-sectional	12.996	TEOAE / AABR / ABR / Tympanometry	Quality-controlled newborn hearing screening proved feasible in a public hospital setting; however, large variations in coverage and high loss-to-follow-up rates compromised the effectiveness of early hearing loss diagnosis.
58	Parangrit et al. (2025)[83]	Retrospective	6.472	OAE / AABR	The implementation of an earlier and more structured newborn hearing screening protocol increased screening coverage and timely diagnosis, although loss to follow-up remained a major limitation in the care pathway.

Caption: BOA = Behavioral Observation Audiometry; AABR = Automated Auditory Brainstem Response; ABR = Auditory Brainstem Response; ASSR = Auditory Steady-State Response; DPOAE = Distortion Product Otoacoustic Emissions; Immittance = Immittance Measures; TEOAE = Transient Evoked Otoacoustic Emissions; Tympanometry = Tympanometry; VRA = Visual Reinforcement Audiometry
Source: Page et al.[24]

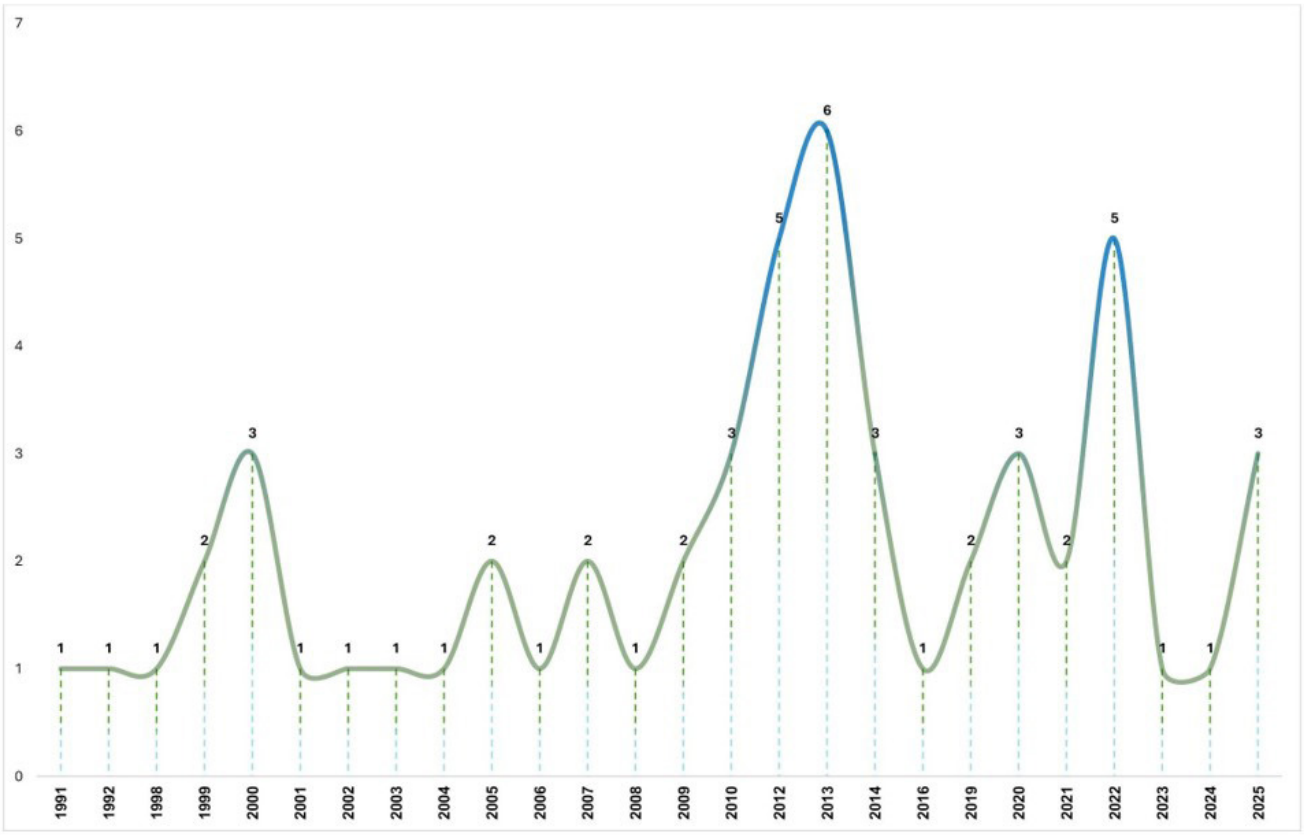


Figure 2. Temporal distribution of studies included in the review

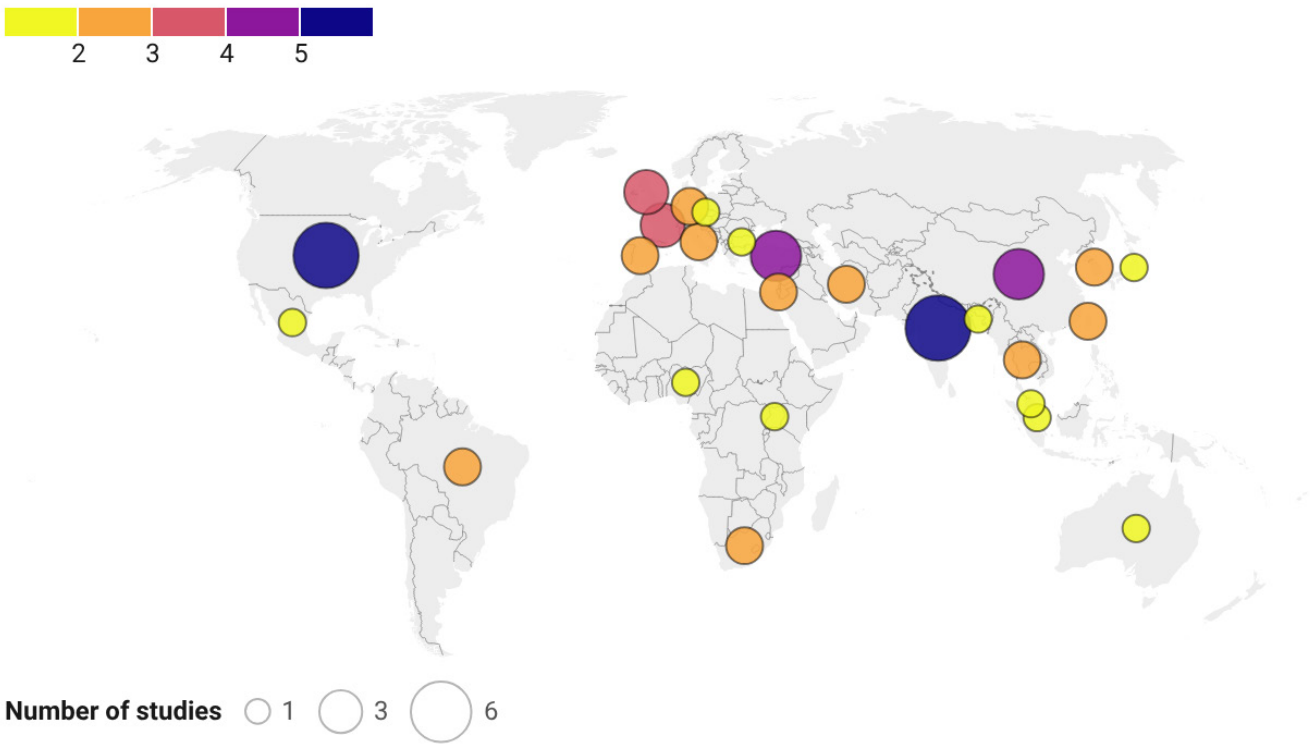


Figure 3. Geographic distribution of studies included in the review. Created with Datawrapper

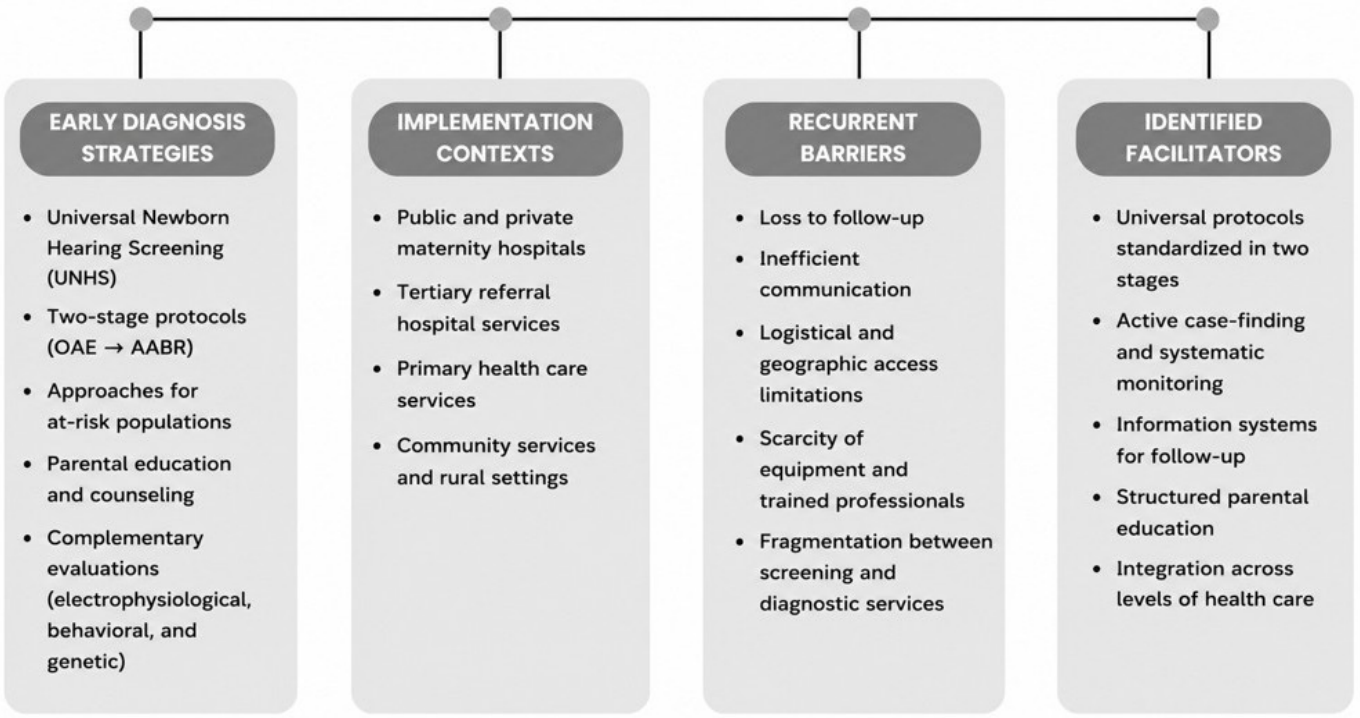


Figure 4. Synthesis of strategies and barriers related to the early diagnosis of hearing loss in infants

DISCUSSION

The temporal and geographic distribution of the included studies reveals important patterns in the scientific literature on the early diagnosis of childhood hearing loss. An increase in publications was observed after 2015, along with a concentration of studies conducted in high-income countries, particularly in the United States, Europe, and Asia, highlighting inequalities in both scientific production and the implementation of structured screening programs.

This scoping review demonstrated substantial variability in healthcare pathways and in the standardization of protocols aimed at the early detection and intervention of childhood hearing loss[26-78]. Such heterogeneity reflects not only methodological differences among studies, but also structural inequalities across healthcare systems, related to the organization of healthcare networks, resource availability, and integration between levels of care. At the same time, the diversity of the analyzed contexts enabled the identification of successful strategies that contribute to the timely diagnosis of hearing impairment, even in settings with logistical constraints[9,26,29,36].

Across the included studies, the combination of otoacoustic emissions and auditory brainstem response remained the cornerstone of early detection strategies, associating greater diagnostic sensitivity with earlier initiation of hearing rehabilitation[27,34,44,72,76]. The historical evolution of Universal Newborn Hearing Screening (UNHS), initially targeted at high-risk neonates and later expanded to the entire neonatal population, demonstrated a consistent impact on reducing the mean age at diagnosis and improving access to hearing interventions, regardless of the healthcare setting[26-29,38,60,76,84].

Despite its widespread adoption, the findings of this review indicate that the effectiveness of UNHS is strongly influenced by the way protocols are operationalized. The use of two-stage protocols, involving the sequential application of OAE and automated ABR, proved effective in reducing false-positive results and improving diagnostic specificity[81,85-87]. Furthermore, retesting performed before hospital discharge or within the first 48–72 hours of life was associated with higher adherence rates and fewer unnecessary referrals, minimizing transient interferences related to the neonatal period[8,33,37,41,52,71,80,87]. These findings reinforce that the quality of healthcare pathways is as important as the choice of the diagnostic method itself.

Programmatic and management-related aspects emerged as critical determinants of screening program performance. Coordination by specialized professionals, exemption from costs in subsequent stages, and integration with regional and national healthcare networks were consistently associated with reduced loss to follow-up[8,78,82]. These results support the interpretation that the effectiveness of UNHS depends less on isolated technology and more on service organization and continuity of care.

Community-based screening models, particularly those incorporating community health workers, demonstrated potential to expand coverage and reduce dropout rates, especially in rural or hard-to-reach areas[35,44]. Such experiences suggest that territorially based strategies may mitigate logistical and geographic barriers, contributing to greater equity in access to hearing healthcare services[35,44,79].

Another relevant finding concerns the limitations of hearing screening as a single event. Included studies demonstrated that infants who "pass" the initial screening may later develop late-onset hearing loss, resulting in delayed diagnosis and intervention[40,66,68,88].

This evidence reinforces the need for continuous clinical and etiological monitoring, with periodic recall for complementary examinations, such as diagnostic ABR and behavioral audiometry, throughout the first years of life.

Among the complementary strategies, genetic screening emerged as a promising approach, particularly for the early identification of hearing loss not detected by conventional auditory methods and for the prevention of conditions associated with ototoxicity[54,89-91]. Similarly, the combined use of electrophysiological tests, such as Auditory Steady-State Response, contributed to estimating hearing loss severity and audiometric configuration, although controversies remain regarding its large-scale feasibility[26,28,40,50,66,92-96].

Taken together, the findings of this review indicate that the effectiveness of early diagnosis programs for childhood hearing loss results from the articulation between technological strategies, service organization, and integration across different levels of healthcare. Fragmentation between screening, diagnosis, and intervention remains one of the main barriers to achieving the internationally recommended continuum of care[12,88].

This review has limitations inherent to its design, including the methodological heterogeneity of the included studies and the predominance of research conducted in high-income countries, which may limit the generalizability of the findings. Nevertheless, by integrating strategies, contexts, and barriers into a single analytical synthesis, this study contributes to a broader understanding of the strengths and weaknesses of early diagnosis programs for childhood hearing loss, highlighting pathways for improving public policies and healthcare practices.

CONCLUSION

This scoping review mapped the main strategies for the early diagnosis of hearing loss in infants, highlighting the predominance of Universal Newborn Hearing Screening based on combined protocols. Although diagnostic methods are well established, considerable variability was observed in protocol operationalization across different healthcare settings, indicating that the effectiveness of early diagnosis depends more on the organization of healthcare pathways and the integration between screening, diagnosis, and follow-up than on isolated technology. The scarcity of studies originating from socially vulnerable settings reveals important gaps in the literature and highlights the need for future investigations addressing different healthcare realities.

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Author contributions

ADSL: conceptualization, data curation, formal analysis, investigation, methodology, visualization, writing – original draft, writing – review & editing; APCF: data curation, investigation, writing – review & editing; SAS, ROF and MCOA: data curation, investigation, validation, writing – review & editing; MHMSLL: data curation, validation, writing – review & editing; KVMT: conceptualization, methodology, supervision, writing – review & editing; HGC: conceptualization, methodology, formal analysis, supervision, writing – review & editing.

Use of artificial intelligence-assisted technology

Artificial intelligence-assisted tools were used to support language revision and improve the clarity of the manuscript. All content was critically reviewed and validated by the authors, who take full responsibility for the integrity, accuracy, and final version of the work.

APPENDIX A. SEARCH STRATEGY ACROSS DATABASES

Database	Search (October 15th 2024, updated January 5, 2026)
Embase	#1. 'newborn'/exp OR 'animals, newborn' OR 'child, newborn' OR 'full term infant' OR 'human neonate' OR 'human newborn' OR 'infant, newborn' OR 'neonatal animal' OR 'neonate' OR 'neonate animal' OR 'neonatus' OR 'newborn animal' OR 'newborn animals' OR 'newborn baby' OR 'newborn child' OR 'newborn infant' OR 'newly born animal' OR 'newly born baby' OR 'newly born child' OR 'newly born infant' OR 'newborn'
	#2. 'hearing impairment'/exp OR 'auditory defect' OR 'deaf' OR 'deafness' OR 'hard of hearing' OR 'hearing damage' OR 'hearing defect' OR 'hearing difficulty' OR 'hearing loss' OR 'hypacousia' OR 'hypacousis' OR 'hypacusia' OR 'hypacusis' OR 'hypakousia' OR 'hypakusis' OR 'hypoacousia' OR 'hypoacousis' OR 'hypoacusia' OR 'hypoacusis' OR 'hypoakusis' OR 'impaired hearing' OR 'hearing impairment'
	#3. 'early diagnosis'/exp OR 'diagnosis, early' OR 'early diagnosis' OR 'newborn screening'/exp OR 'mass screening, newborn' OR 'neonatal screening' OR 'screening, newborn' OR 'newborn screening'
	#4. #1 AND #2 AND #3
	#5. #4 AND [embase]/lim NOT ([embase]/lim AND [medline]/lim)
LILACS	(mh:"Recém-Nascido" OR "Recém-Nascido" OR "Criança Recém-Nascida" OR "Crianças Recém-Nascidas" OR "Lactente Recém-Nascido" OR "Lactentes Recém-Nascidos" OR neonato neonatos "Recém-Nascido (RN)" OR "Recém-Nascidos" OR "Newborn Infant" OR "Recién Nacido" OR mh:m01.060.703.520*) AND (mh:"Perda Auditiva" OR "Perda Auditiva" OR "Deficiência Auditiva" OR hipoacusia OR "Perda Auditiva Transitória" OR "Perda da Audição" OR "Perda da Capacidade Auditiva" OR "Surdez Transitória" OR "Hearing Loss" OR "Pérdida Auditiva" OR mh:c09.218.458.341* OR mh:c10.597.751.418.341* OR mh:c23.888.592.763.393.341*) AND (mh:"Diagnóstico Precoce" OR "Diagnóstico Precoce" OR "Early Diagnosis" OR "Diagnóstico Precoz" OR mh:e01.390* OR mh:"Triagem Neonatal" OR "Triagem Neonatal" OR "Rastreamento Neonatal" OR "Rede Estadual" de "Triagem Neonatal" OR "Triagem Neonatal Universal" OR "Triagem do Recém-Nascido" OR "Neonatal Screening" OR "Tamizaje Neonatal" OR mh:e01.370.225.910* OR mh:e01.370.500.580* OR mh:e05.200.910* OR mh:e05.318.308.980.438.580.580* OR mh:n02.421.726.233.443.816* OR mh:n05.715.360.300.800.438.500.575* OR mh:n06.850.520.308.980.438.580.580* OR mh:n06.850.780.500.580*)
PubMed/ Medline	#1. "Infant"[Mesh] OR Infants OR "Infant, Newborn"[Mesh] OR "Newborn Infant" OR "Newborn Infants" OR Neonate OR Neonates OR Newborns OR Newborn
	#2. "Hearing Loss"[Mesh] OR "Hearing Impairment"
	#3. "Early Diagnosis"[Mesh] OR "Early Detection of Disease" OR "Disease Early Detection" OR "Mass Screening"[Mesh] OR "Mass Screenings" OR Screening OR Screenings OR "Neonatal Screening"[Mesh] OR "Neonatal Screenings" OR "Newborn Screening" OR "Newborn Screenings" OR "Newborn Infant Screening"
	#4. #1 AND #2 AND #3
Scopus	(TITLE-ABS-KEY (infant OR infants OR "Newborn Infant" OR "Newborn Infants" OR neonate OR neonates OR newborns OR newborn) AND TITLE-ABS-KEY ("Hearing Loss" OR "Hearing Impairment") AND TITLE-ABS-KEY ("Early Diagnosis" OR "Early Detection of Disease" OR "Disease Early Detection" OR "Mass Screening" OR "Mass Screenings" OR screening OR screenings OR "Neonatal Screening" OR "Neonatal Screenings" OR "Newborn Screening" OR "Newborn Screenings" OR "Newborn Infant Screening"))
Web of Science	Infant OR Infants OR "Newborn Infant" OR "Newborn Infants" OR Neonate OR Neonates OR Newborns OR Newborn (Topic) AND "Hearing Loss" OR "Hearing Impairment" (Topic) AND "Early Diagnosis" OR "Early Detection of Disease" OR "Disease Early Detection" OR "Mass Screening" OR "Mass Screenings" OR Screening OR Screenings OR "Neonatal Screening" OR "Neonatal Screenings" OR "Newborn Screening" OR "Newborn Screenings" OR "Newborn Infant Screening" (Topic)
Google Scholar	"Newborn Infant" AND "Hearing Loss" AND "Early Diagnosis" OR "Neonatal Screening"
ProQuest	Infant OR Infants OR "Newborn Infant" OR "Newborn Infants" OR Neonate OR Neonates OR Newborns OR Newborn (Topic) AND "Hearing Loss" OR "Hearing Impairment" (Topic) AND "Early Diagnosis" OR "Early Detection of Disease" OR "Disease Early Detection" OR "Mass Screening" OR "Mass Screenings" OR Screening OR Screenings OR "Neonatal Screening" OR "Neonatal Screenings" OR "Newborn Screening" OR "Newborn Screenings" OR "Newborn Infant Screening" (Topic)

APPENDIX B. REASONS FOR EXCLUSION OF STUDIES *(N = 355)*

Nº	Author, Year	Reason for exclusion*
[1]	Pérez et al., 2009	4
[2]	Abdul Hadi et al., 2012	1
[3]	Abdulai et al., 2020	2
[4]	Abdullah et al., 2006	1
[5]	Adelola et al., 2010	5
[6]	Ahmed et al., 2018	1
[7]	Aiyer; Parikh, 2009	1
[8]	Alberti et al., 1983	4
[9]	Al-Kandari; Alshuaib, 2007	5
[10]	Alarcón Avila et al., 2025	2
[11]	Allen; Lambert, 1990	4
[12]	Almenar Latorre et al., 2002	5
[13]	Alves De Sousa et al., 1996	2
[14]	Anderssen et al., 2002	3
[15]	Angrisani et al., 2012	2
[16]	Ansari, 2022	2
[17]	Applebaum, 1999	2
[18]	Aras Öztürk et al., 2018	3
[19]	Ardic, 2017	4
[20]	Arnold et al., 2006	5
[21]	Arslan et al., 2013a	2
[22]	Arslan et al., 2013b	2
[23]	Ataoğlu et al., 2019	1
[24]	Azevedo, 1991	7
[25]	Azevedo et al., 2004	7
[26]	Azizi et al., 2016	1
[27]	Babac; Djerič; Ivankoviğ, 2007	5
[28]	Back; Ho, 2011	3
[29]	Backous, 2002	2
[30]	Bagatto et al., 2020	1
[31]	Bai et al., 2024	1
[32]	Bansal; Gupta; Nagarkar, 2008	3
[33]	BarskyFirkser; Sun, 1997	1
[34]	Bartmeyer; Navarini; Carvalho, 2025	3
[35]	Begum et al., 2024	3
[36]	Bellia et al., 2020	1
[37]	Benito Orejas et al., 2008a	3
[38]	Benito Orejas et al., 2008b	3
[39]	Benito Orejas; Silva Rico, 2017	2
[40]	Berger et al., 2012	4
[41]	Bertoldi; Manfredi; Mitre, 2017	4
[42]	Bevilacqua et al., 2010	3
[43]	Bhalot et al., 2023	3
[44]	Bhatia et al., 2013	4
[45]	Biaggio et al., 2015	2
[46]	Bianchin et al., 2022	4
[47]	Biscegli et al., 2015	3
[48]	Bishnoi et al., 2019	2
[49]	Bonelli et al., 2000	4
[50]	Botasso; Lima; Correa, 2022a	4
[51]	Botasso; Lima; Correa, 2022b	4
[52]	Botelho et al., 2010	3
[53]	Bradford et al., 1985	2
[54]	Bradley; Barbera, 2001	2
[55]	Bravo A et al., 2017	5

*1. Wrong study design; 2. Wrong publication type; 3. Non-specific evaluation strategy; 4. Wrong population; 5. Wrong objective; 6. no response from the author; 7. Not found

APPENDIX B. CONTINUED...

Nº	Author, Year	Reason for exclusion*
[56]	Brockow et al., 2011a	3
[57]	Brockow et al., 2011b	3
[58]	Bubbico et al., 2008	1
[59]	Bubbico; Tognola; Grandori, 2017	3
[60]	Buser et al., 2003	5
[61]	Calcutt et al., 2016	5
[62]	Calevo et al., 2007	3
[63]	Campos Banãles et al., 2003	4
[64]	Campos et al., 2003	4
[65]	Canale et al., 2006	4
[66]	Cao-Nguyen; Kos; Guyot, 2007	4
[67]	Cardoso et al., 2009	4
[68]	Cassidy; Ditty, 2001	1
[69]	Ceccato et al., 1996	2
[70]	ğerný et al., 2003	3
[71]	Chadha; Bais, 1997	4
[72]	Champion, 2021	4
[73]	Chang et al., 2012	1
[74]	Chen et al., 2012	4
[75]	Chen et al., 2017	4
[76]	Chibisova et al., 2014	3
[77]	Chiriboga et al., 2021	2
[78]	Choi et al., 2022	4
[79]	Chu et al., 2015	1
[80]	Chung; Oh; Park, 2020a	6
[81]	Chung; Oh; Park, 2020b	6
[82]	Cianfrone et al., 2018	4
[83]	Cianfrone et al., 2021	1
[84]	Colella-Santos et al., 2013a	4
[85]	Colella-Santos et al., 2013b	1
[86]	Coll; Régnier, 1988	6
[87]	Collins et al., 2022	7
[88]	Costa et al., 2015	3
[89]	Cox; Toro, 2001	1
[90]	Cundall, 1997	7
[91]	Curcin; Sitka; Rasinski, 1998	6
[92]	Curnock, 1993	2
[93]	Da Silva et al., 2017	2
[94]	Dalzell et al., 2000	3
[95]	Dantas et al., 2009	3
[96]	Davis; Hind, 2003	1
[97]	Daykhes et al., 2017	3
[98]	De Barros Boishardy et al., 2005	3
[99]	De González Dios; Mollar Maseres, 2005	3
[100]	De Leenheer et al., 2011	1
[101]	De Mattos et al., 2009	2
[102]	Delgado Domínguez, 2011	2
[103]	Deng et al., 2022	3
[104]	Desloovere et al., 2000	6
[105]	Dlouhá et al., 2002	7
[106]	Downs, 1995	1
[107]	Duci A et al., 2000	2
[108]	Durante et al., 2005	4
[109]	Durante et al., 2004	7
[110]	Eibenstein et al., 2014	2

*1. Wrong study design; 2. Wrong publication type; 3. Non-specific evaluation strategy; 4. Wrong population; 5. Wrong objective; 6. no response from the author; 7. Not found

APPENDIX B. CONTINUED...

Nº	Author, Year	Reason for exclusion*
[111]	Eiserman et al., 2008	4
[112]	Elpers et al., 2016	1
[113]	Farhat et al., 2014	4
[114]	Feroz, et al., 2025	3
[115]	Felden et al., 2017	7
[116]	Fernandes; Nozawa, 2010	1
[117]	Fernandez Martinez et al., 1995	1
[118]	Ferro et al., 2007	4
[119]	Findlen; Malhotra; Hunter,	1
[120]	Fink et al., 2022	1
[121]	Fitzpatrick; Durieux-Smith; Whittingham, 2010	4
[122]	François et al., 2011	1
[123]	Fujikawa; Yoshinaga-Itano, 2000	2
[124]	Fukushima et al., 2008	1
[125]	Gáborján et al., 2019	3
[126]	Gaborján et al., 2022	3
[127]	Galhotra; Sahu, 2019	3
[128]	Garbaruk et al., 2021	2
[129]	Gavilan Cellie, 1993	2
[130]	Geal-Dor et al., 2002	3
[131]	Gellrich et al., 2024	5
[132]	Gentiletti-Faenze et al., 2003	2
[133]	Georgescu; Vladareanu, 2015	4
[134]	Giordano; Marchegiani; Germiller, 2015	7
[135]	Godoy B; Bustamante M, 2006	1
[136]	González De Aledo Linos et al., 2005	3
[137]	González de Dios; Mollar Maseres; Rebagliato Russo, 2005	1
[138]	González Díaz et al., 2020	5
[139]	González; Díaz; Mora, 2022	5
[140]	González; Fernández de Soto; Torres, 2012	2
[141]	Gordo et al., 1994	3
[142]	Granell; Martin, 2011	2
[143]	Greczka et al., 2015	3
[144]	Greczka et al., 2018	1
[145]	Grégoire, 1996	3
[146]	Greville; Keith, 1978	3
[147]	Groh et al., 1999	3
[148]	Guastini et al., 2010	1
[149]	Guilhoto; Quintal; Da Costa, 2003	4
[150]	Guimarães; Barbosa, 2012	1
[151]	Gulati et al., 2022	1
[152]	Halder et al., 2025	6
[153]	Hall; Brosch; Hoffmann, 2020	1
[154]	Hanschmann; Berger, 2010	7
[155]	Harrison et al., 2000	2
[156]	Hatzopoulos et al., 2001	5
[157]	Hayes, 2002	2
[158]	Helge et al., 2005	3
[159]	Hergils, 2000	2
[160]	Hoffmann et al., 2013	1
[161]	Hosforddunn et al., 1987	5
[162]	Huang et al., 2014	4
[163]	Huang et al., 2023	2
[164]	Huang et al., 2009	3
[165]	Huang et al., 2017	4

*1. Wrong study design; 2. Wrong publication type; 3. Non-specific evaluation strategy; 4. Wrong population; 5. Wrong objective; 6. no response from the author; 7. Not found

APPENDIX B. CONTINUED...

Nº	Author, Year	Reason for exclusion*
[166]	Huarte Irujo, 2003	1
[167]	Irfan et al., 2024	2
[168]	Iwanicka-Pronicka et al., 2008	4
[169]	Izumets; Nezhivenko; Murashko, 2015	2
[170]	Jacob et al., 2022	4
[171]	Jacobson; Jacobson, 1990	1
[172]	Jacobson, 2001	6
[173]	Jakubikova et al., 1999	7
[174]	Jakubíková; Kabátová; Závodná, 2003	1
[175]	Januário et al., 2015	1
[176]	Jayne et al., 2023	3
[177]	Johnson et al., 2005	1
[178]	Kanji; Khoza-Shangase, 2012	4
[179]	Kanji; Krabbenhoft, 2018	4
[180]	Kawata et al., 2011	1
[181]	Keefe et al., 2000	2
[182]	Kemper, 2011	4
[183]	Kerschner et al., 2004	3
[184]	Kiese-Himmel; Schroff; Kruse, 1997	1
[185]	Kim et al., 2011	7
[186]	Koester; Nekahm-Heis; Zorowka, 2002	7
[187]	Konukseven et al., 2010	4
[188]	Korres et al., 2006	5
[189]	Korres et al., 2008	2
[190]	Krauss M et al., 2013	1
[191]	Krishnan, 2009	3
[192]	Kumar; Gupta; Sinha, 2017	3
[193]	Lan et al., 2024	1
[194]	Langagne et al., 2008	6
[195]	Lee-Ramos et al., 2023	1
[196]	Leonhardt; Müller, 2008	3
[197]	Lewis; Racai; Bevilacqua, 1987	2
[198]	Lewis et al., 2010	2
[199]	Lim; Daniel, 2008	1
[200]	Lima; Marba; Santos, 2005	4
[201]	Lima et al., 2010	4
[202]	Lima et al., 2015	4
[203]	Ling et al., 2015	7
[204]	Liu et al., 2014	4
[205]	Liu et al., 2001	7
[206]	Lopes et al., 2020	4
[207]	Lotfi; Movallali, 2007;	4
[208]	Low et al., 2005	3
[209]	Lowell, 1960	1
[210]	Magnani et al., 2015	1
[211]	Magnusson; Persson; Sundelin, 2001;	4
[212]	Mahmood et al., 2020	3
[213]	Maluleke; Khoza-Shangase; Kanji, 2019	1
[214]	Maniuc; Chiaburu-Chiosa, 2018	4
[215]	Marco Algarra; Pitarch Ribes; Morant Ventura, 1996	5
[216]	Marinho et al., 2020	1
[217]	Marn, 2000	1
[218]	Marn, 2012	6
[219]	Martines et al., 2007	2
[220]	Martines et al., 2014	1

*1. Wrong study design; 2. Wrong publication type; 3. Non-specific evaluation strategy; 4. Wrong population; 5. Wrong objective; 6. no response from the author; 7. Not found

APPENDIX B. CONTINUED...

Nº	Author, Year	Reason for exclusion*
[221]	Martínez et al., 2003a	4
[222]	Martínez et al., 2003b	4
[223]	Martínez-Pacheco; Ferrán de la Cierva; García-Purriños, 2016	4
[224]	Mason; Herrmann, 1998	3
[225]	Mathur; Dhawan, 2007	4
[226]	Matschke; Plath, 1985a	7
[227]	Matschke; Plath, 1985b	2
[228]	Mattos et al., 2009	2
[229]	Mauk et al., 1991	4
[230]	Maxon et al., 1993	5
[231]	Meier et al., 2004	2
[232]	Mencher, 1974	1
[233]	Meyer et al., 2012	5
[234]	Mijares Nodarse et al., 2006	2
[235]	Molini et al., 1996	2
[236]	Molteni, 2006	7
[237]	Monteiro, 2004	2
[238]	Montovani; Fioravanti; Tamashiro, 1996	2
[239]	Moradi-Joo et al., 2024	3
[240]	Morgan; Canalis, 1991	2
[241]	Mukkun, 2021	3
[242]	Murray; Javel; Watson, 1985	2
[243]	Navarro Rivero et al., 1999	4
[244]	Nennstiel-Ratzel et al., 2007	3
[245]	Newton et al., 1999	1
[246]	Ng; Yun, 1992	2
[247]	Ng et al., 2004	1
[248]	Norton et al., 2000a	1
[249]	Norton et al., 2000b	2
[250]	Obeidat et al., 2024	1
[251]	Olarte et al., 2019	4
[252]	Olusanya, 2001	4
[253]	Olusanya; Ebuehi; Somefun, 2009	1
[254]	Onoda; Azevedo; Santos, 2011	3
[255]	Paat-Ahi; Sikkut; Laarmann, 2014	5
[256]	Pastorino et al., 2005	3
[257]	Paul, 2003	2
[258]	Pedersen et al., 2008	5
[259]	Pelosi et al., 1998	1
[260]	Pitathawatchai; Khaimook; Kirtsreesakul, 2019	3
[261]	Pitathawatchai; Wanachottrakul; Prayuenyong, 2025	6
[262]	Plinkert et al., 1990	1
[263]	Plinkert; Delb, 2001a	1
[264]	Plinkert; Delb, 2001b	3
[265]	Poblano et al., 2000	1
[266]	Polski et al., 2014	3
[267]	Poncet; Chaperon, 1983	4
[268]	Prieve et al., 2013	3
[269]	Prieve; Stevens, 2000	2
[270]	Prince et al., 2003	1
[271]	Ptok, 2004	2
[272]	Radü, 1985	4
[273]	Raghuwanshi et al., 2019	3
[274]	Appanaitis; Rahimian, 2018	5
[275]	Ren et al., 2025	3

*1. Wrong study design; 2. Wrong publication type; 3. Non-specific evaluation strategy; 4. Wrong population; 5. Wrong objective; 6. no response from the author; 7. Not found

APPENDIX B. CONTINUED...

Nº	Author, Year	Reason for exclusion*
[276]	Reis et al., 2019	1
[277]	Richard et al., 2025	6
[278]	Rodrigues, 2020	2
[279]	Roman et al., 2001	4
[280]	Ruiz De La Cuesta; Juste Ruiz; Cortés Castell, 2018	3
[281]	Saitoh et al., 2002	3
[282]	Saki et al., 2017	5
[283]	Santos-Ceballos et al., 2020	7
[284]	Sarno; Clemis, 1980	2
[285]	Sassada et al., 2005	7
[286]	Sass-Lehrer, 2004	2
[287]	Satish; Anil Kumar; Viswanatha, 2019	3
[288]	Schade, 2008	2
[289]	Schauseil-Zipf; Von Wedel, 1988	5
[290]	Schmidt et al., 2007	3
[291]	Schönweiler et al., 2002	4
[292]	Sedano M; San Martín U; Rahal E, 2018	3
[293]	Seguya et al., 2021	4
[294]	Sente; Aleksov-Hatvan, 2006	2
[295]	Shang et al., 2016	4
[296]	Sharma et al., 2022	4
[297]	Shehata-Dieler et al., 2000	3
[298]	Shi et al., 2025	3
[299]	Shirane et al., 2020	4
[300]	Shulman et al., 2010	1
[301]	Solanellas Soler, 2009	2
[302]	Sun et al., 2003	7
[303]	Sun et al., 2009	4
[304]	Sun et al., 2015	4
[305]	Sun et al., 2019	7
[306]	Swanepoel; Delport; Swart, 2004	3
[307]	Szyfter et al., 2008	2
[308]	Szyfter et al., 2016	1
[309]	Tanon-Anoh; Sanogo-Gone; Kouassi, 2010	5
[310]	Tham; Lee; Joseph, 2010	1
[311]	Todd, 2006	3
[312]	Trinidad Ruiz et al., 2005	4
[313]	Tufatulin et al., 2023	2
[314]	Turan; Bas, 2019	1
[315]	Tzanakakis et al., 2016	6
[316]	Ulusoy et al., 2013	3
[317]	Ulusoy et al., 2014	2
[318]	Uppenkamp et al., 1992	1
[319]	Valencia et al., 2008	4
[320]	Van Straaten et al., 2001;	1
[321]	Van Straaten; Groote; Oudesluys-Murphy, 1996	1
[322]	Vernier et al., 2014	7
[323]	Verrue; Smets, 2012	7
[324]	Vila et al., 2004	2
[325]	Voegeli, 1979	2
[326]	Vohr et al., 2002	5
[327]	Vos; Lagasse; Levêque, 2013	3
[328]	Vranješ et al., 2012	3
[329]	Wang; Xing; Liu, 2002	7
[330]	Wang et al., 2022	3

*1. Wrong study design; 2. Wrong publication type; 3. Non-specific evaluation strategy; 4. Wrong population; 5. Wrong objective; 6. no response from the author; 7. Not found

APPENDIX B. CONTINUED...

Nº	Author, Year	Reason for exclusion*
[331]	Watkin, 1999	2
[332]	Weichbold; Nekahm-Heis; Welzl-Müller, 2005	1
[333]	Welzl-Müller; Stephan, 2001	1
[334]	Widen et al., 2000	1
[335]	Wong et al., 2021	1
[336]	Wu; Huang; Kao, 1998	7
[337]	Xu et al., 2006	2
[338]	Xu et al., 2003	2
[339]	Xu; Li, 2005a	2
[340]	Xu; Li, 2005b	3
[341]	Xu; Cheng; Yang, 2011	2
[342]	Yao et al., 2013	4
[343]	Yigit et al., 2020	4
[344]	Yılmazer et al., 2016	1
[345]	Yoshinaga-Itano, 2003	3
[346]	Yoshinaga-Itano; Apuzzo, 1998	1
[347]	Yoshinaga-Itano; Gravel, 2001	1
[348]	Yousefi et al., 2013a	3
[349]	Yousefi et al., 2013b	3
[350]	Zeng et al., 2020	3
[351]	Zhang; Li; Zheng, 2014	2
[352]	Zhang et al., 2004	2
[353]	Zhao et al., 2003	1
[354]	Zwicker; Schorn, 1990	2
[355]	Zych et al., 2018	2

*1. Wrong study design; 2. Wrong publication type; 3. Non-specific evaluation strategy; 4. Wrong population; 5. Wrong objective; 6. no response from the author; 7. Not found

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