

Evaluation of Hearing Loss after Failed Neonatal Hearing Screening

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Objective We evaluated the causes of hearing loss found after failed universal newborn hearing screening and compared the results with the previously used behavioral observation test (Ewing/CAPAS).

Study design Hearing loss in neonates, born between September 1999 and October 2007 and referred to our center after failed screening, was determined by audiologic testing and physical examination.

Results In 340 included neonates the results of hearing tests were as follows: normal hearing 21.2%, conductive hearing loss 20.3%, and sensorineural hearing loss (SNHL) 57.9%. Children referred from the neonatal intensive care unit were more at risk of SNHL (71%) than those from the well-baby clinics (54%). Hearing aids were provided at a median age of 8 months. The positive predictive value of SNHL screening was 54% for a child from a well-baby clinic and 71% for a child from the neonatal intensive care unit.

Conclusion The use of universal newborn hearing screening results in a lower proportion of infants positive because of otitis media with effusion than the previously used Ewing/CAPAS test (20% vs 59-81%). Second, screening leads to identification of hearing loss and intervention at a younger age (8 months vs 15-18 months). Third, the positive predictive value for SNHL has improved (54% vs 2%). (*J Pediatr* 2009;155:646-50).

Since 1965 the hearing of children in the Netherlands has been tested through a nationwide screening program aimed at early detection of permanent hearing loss. The test first used was the "Compact Amsterdam Pede-Audiometric Screener" (CAPAS) or Ewing-test, a behavioral observation test associated with 4 disadvantages. First, the lower age limit for this test is 9 months.¹ Therefore therapy usually did not start before the age of 15 to 18 months,² notwithstanding the fact that earlier identification and intervention of hearing loss results in significantly better language ability.^{3,4} Second, the Ewing/CAPAS test is unsuitable for children with developmental retardation or visual impairment,¹ allowing only 80% of children in the Netherlands to go through the complete screening.⁵ Third, the ears cannot be measured separately. Fourth, the positive predictive value for sensorineural hearing loss was 2% or less.² A substantial proportion (59% to 81%) of positive screening results was due to temporary conductive hearing loss caused by otitis media with effusion (OME).⁶ Identifying this type of hearing loss was not the aim of the screening, because early intermittent OME has no or minimal effect on language development.^{7,8}

A new test became part of a universal newborn hearing screening (UNHS) program started in 2002 and was implemented fully in 2006. The aim is to identify permanent conductive or sensorineural hearing loss before the age of 3 months and to start intervention and counseling before the age of 6 months,⁹ in accordance with the screening guidelines formulated by the Joint Committee on Infant Hearing.¹⁰

Newborn infants typically are tested within a few days after birth by 2-stage otoacoustic emission (OAE) screening. Testing takes place in the well-baby clinic or at home. A positive OAE screening result is followed by automated auditory brainstem response (AABR) testing.¹¹ In the Netherlands, 98.6% of the children born are screened with this program.¹

The procedure is different for newborns admitted to a neonatal intensive care unit (NICU). These are believed to be more at risk of hearing loss than healthy infants.¹² A recent nationwide cohort study in Dutch NICU infants determined a prevalence of hearing loss of 3.2%.¹³ Since 1998 a 2-stage AABR hearing-screening program has been used in the Dutch NICUs, with a coverage rate of at least 98%.¹⁴ This program allows the detection of auditory neuropathy or neural conduction disorders.^{10,15} To avoid false-negative test results, infants are screened just before discharge.¹⁴ A child who fails 2 (NICU) or 3 (well-baby clinic) unilateral or bilateral tests is referred to an audiology center for further diagnostic assessment.^{1,16}

AABR	Automated auditory brainstem response
ABR	Auditory brainstem response
CAPAS	Compact Amsterdam Pede-Audiometric Screener
HL	Hearing loss
IQR	Interquartile range
NICU	Neonatal intensive care unit
OAE	Otoacoustic emission
OME	Otitis media with effusion
SNHL	Sensorineural hearing loss
UNHS	Universal newborn hearing screening

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Although various screening methods and the (cost) effectiveness of a UNHS have been studied widely, little is known about prevalence of (permanent) hearing loss in children who failed neonatal screening and the final diagnosis in these children. The aim of this study is to evaluate the causes of hearing loss found after failed universal newborn hearing screening and to compare the results with the earlier-used Ewing/CAPAS screening.

Methods

This is a retrospective cohort study of neonates referred to our center after failed neonatal hearing screening. We collected clinical record and audiometric data from NICU infants born between September 1, 1999, and October 1, 2007, and infants referred from well-baby clinics born between January 1, 2002, (or later if the new hearing screening program was implemented later in those areas) and October 1, 2007.

We defined NICU infants as neonates admitted to a neonatal intensive care unit for a period longer than 24 hours.¹ Subnormal hearing was defined as hearing loss below 30 dB when measured by formal auditory brainstem response (ABR) testing. Hearing loss was defined as unilateral or bilateral hearing loss of 30 dB or more. Sensorineural hearing loss (SNHL) was defined as cochlear hearing loss or retrocochlear hearing loss (eg, auditory neuropathy). SNHL was defined as “genetic” if the child had a syndrome associated with SNHL, if a DNA mutation associated with SNHL was found, or if a first or second-degree relative had sensorineural hearing loss since childhood. Genetic SNHL was divided into nonsyndromic (not associated with distinctive clinical features) or syndromic (distinctive clinical features and identification of the causal mutation).

Conductive hearing loss was defined as “genetic” if the child had a syndrome associated with conductive hearing loss as a result of causes other than OME, or in cases of craniofacial anomalies, such as atresia or microtia of the outer or middle ear, associated with permanent conductive hearing loss. “First diagnosis” was defined as the diagnosis made on first consultation. “Diagnosis at last consultation” was defined as the last consultation before discharge from the outpatient clinic or the last consultation before April 2008 (when data analysis was started).

Children referred from well-baby clinics in the greater Rotterdam area, including the province Zeeland in the southwest of the Netherlands, are seen at our referral center in the Erasmus MC–Sophia Children’s Hospital. This area has about 1.6 million inhabitants with an annual birth rate of 20 000. Infants from the hospital’s NICU also are seen at the center. We aim to have the first consultation before the age of 6 weeks.

Hearing loss was classified on the basis of the hearing tests performed by an audiologist and the physical examination by an otorhinolaryngologist, including otoscopy. In some cases the cause of hearing loss was obvious, in other cases additional tests were needed, such as a blood test for congenital infections or gene mutations or further audiologic tests.

If a genetic cause for the hearing loss was presumed, genetic counseling was offered. Depending on the clinical history of the child, a blood sample was taken or audiograms of family members were obtained.

If there was indication of an intrauterine or perinatal infection (eg, prematurity, maternal fever, sensorineural hearing loss with unknown origin), antibody screening for toxoplasmosis, others (syphilis), rubella, cytomegalovirus, or herpes simplex virus (TORCH)¹⁷ infections were performed.

Risk factor analysis was carried out in every newborn diagnosed with hearing loss, including an evaluation of known possible risk factors for hearing loss.^{13,18–22} Audiometry included formal ABR (ie, nonautomated testing), OAEs, and tympanometry. The results of the ABR (eg waveform) were essential for defining the type of HL; OAEs and tympanometry supported the diagnosis. ABR was measured by a special-purpose ABR device developed at our department with a Toennies amplifier. A 2-channel recording was made by connecting the positive inputs to the child’s vertex and the negative inputs to both mastoids. A broadband click stimulus was used, with a repetition frequency of 23 Hz. A maximum stimulus level of 90 dB (to 100 dB) was used to find the I-V interpeak latency. After this, the stimulus level was reduced to find wave V threshold level. The hearing loss was 10 dB lower than the found ABR response threshold.

Transient evoked OAEs were recorded with an Otodynamics Echoport ILO 288 USB-II V6 software (Otodynamics, London, United Kingdom). Tympanometry was done with an Interacoustics AT 235 h device (Interacoustics USA, Eden Prairie, Minnesota), with a 1-kHz and a 226-Hz probe stimulus. Data of all patients were entered in a central database. Statistical analysis was performed with SPSS 14.0 statistical software (SPSS Inc, Chicago, Illinois).

We used the median and interquartile range (IQR) because the data were not normally distributed. The positive predictive value was calculated as the number of children with SNHL at last consultation divided by the total number of children with a failed screening result.

Results

During the study period 346 newborns were referred to our tertiary referral center, of whom 6 newborns (1.73%) were lost to follow-up. Thus 340 newborns, 261 from the well-baby clinics and 79 from the NICU, were included in the study. Population characteristics are shown in [Table I](#).

Table I. Population characteristics

	Well-baby clinic	NICU
Number	261	79
Male sex	145 (56%)	47 (60%)
Median gestational age (weeks)	39.6	34.7
Median birth weight (g)	3280	2015
Implementation hearing screening (y)	2002	1998

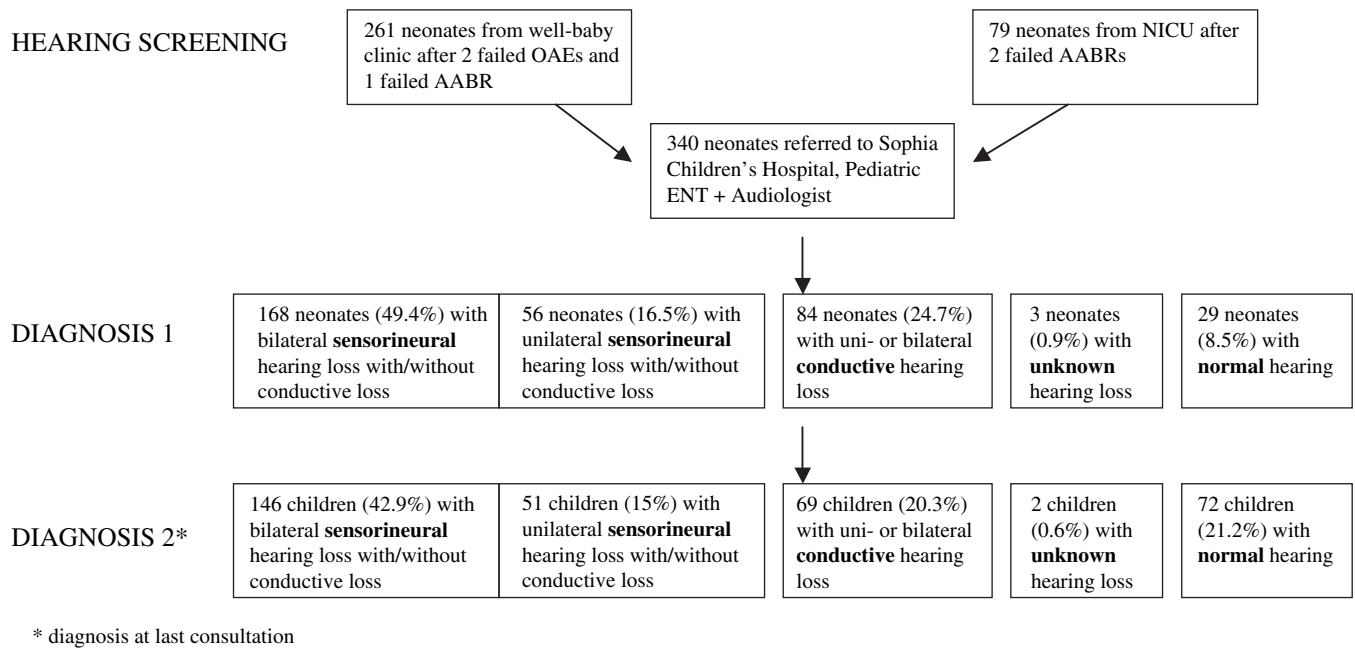


Figure. Flowchart of children after failed neonatal hearing screening.

Twenty-nine (8.5%) were found to have normal hearing at first consultation and were discharged. Eighty-four (24.7%) had pure conductive hearing loss in 1 or both ears. Fifty-six (16.5%) had unilateral sensorineural hearing loss with or without conductive loss in 1 or both ears; 168 (49.4%) had bilateral sensorineural hearing loss with or without conductive loss (**Figure**).

All children with hearing loss entered a follow-up program. The median follow-up time was 29 months (IQR 16-42 months). Children with hearing loss exceeding 40 dB were referred for hearing aids. The median age for implementation of hearing aids was 8 months (IQR 6-12 months).

The diagnosis at last consultation could differ from those at first consultation. At the last consultation, the number of children with normal hearing had increased to 72 (21.2%). The number of children with pure conductive hearing loss had decreased to 69 (20.3%); 17.1% of these cases were due to OME, and 3.2% were of genetic origin (eg, microtia or atresia of the outer or middle ear, or a syndrome associated with middle ear defects (**Table II**)).

The number of children at last consultation with SNHL in one ear was 51 (15%) and that with SNHL in both ears was 146 (42.9%). In total 197 children (57.9%) had SNHL; 1.8% of SNHL was due to intrauterine infection (1.5% rubella and 0.3% CMV), 13.3% was of genetic origin (5.9% syndromic and 7.4% non-syndromic). In 42.9% children with SNHL, the origin was unknown; for these children, only possible risk factors^{13,18-22} could be determined.

The proportion of children with normal hearing was lower in the NICU group than in the group referred from the well-baby clinics (12.7% vs 23.8%). Furthermore, sensorineural

hearing loss was more frequent in the NICU group (70.9% vs 54.0%). The positive predictive value of the screening for SNHL was 54% for children from the well-baby clinics and 71% for the children in the NICU.

Discussion

We evaluated all newborns who failed the universal hearing screening in our tertiary hospital. The follow-up rate for evaluation was high: only 6 referred neonates (1.73%) failed to present at the outpatient clinic, whereas in other studies 29%²³ to 69%²⁴ of the children were lost to follow-up after failed screening. We speculate the good communication between screeners from well-baby clinics and audiologists accounted for the high rate of follow-up. A letter of referral was received after every “failed” screening. Once a month all referred patients were discussed in joint meetings. All NICU babies in our hospital with failed hearing screening results also were referred.

Newborns from the well-baby clinic were tested by a 2-stage OAE screening and subsequently by AABR if necessary. NICU babies were tested by a 2-stage AABR screening. OAE screening has a disadvantage in that OAEs may be completely normal in patients with auditory neuropathy, whereas the AABR would show a “refer.”^{25,26}

Therefore the program for children from the well-baby clinics could fail to detect this type of hearing loss. Furthermore, OAE screening is slightly more sensitive for OME. The AABR screening in the third stage is intended, however, to reduce this type of positive result.¹ We distinguished between unilateral and bilateral sensorineural hearing loss

Table II. Diagnosis at last consultation

	Well-baby clinic		NICU		Total	
	%	n	%	n	%	n
Normal hearing	23.8	62	12.7	10	21.2	72
Conductive HL	21.8	57	15.2	12	20.3	69
OME	18.4	48	12.7	10	17.1	58
Genetic	3.4	9	2.5	2	3.2	11
Sensorineural HL	54	141	70.9	56	57.9	197
TORCH Agents						
Rubella	1.9	5	0	0	1.5	5
CMV	0.4	1	0	0	0.3	1
Genetic						
Nonsyndromic	8.8	23	2.5	2	7.4	25
Syndromic	3.1	8	15.2	12	5.9	20
Unknown origin	39.8	104	53.2	42	42.9	146
Unknown	0.4	1	1.3	1	0.6	2

(SNHL) because we believe these cannot be taken together as a mixed hearing loss group, unlike some other authors.^{27,28} Our screening program aims to identify unilateral or bilateral SNHL. Children with unilateral SNHL were closely monitored until the age of 4 years; treatment often was not necessary. In contrast, children with bilateral hearing loss need hearing aids as early as possible to develop good language skills.^{3,4}

At the first consultation the proportion of children diagnosed with SNHL was higher than at the last consultation, probably because of delayed auditory pathway maturation. We found that the age-corrected I-V interpeak latency often was longer at the first consultation than at a later consultation. As the interpeak latency normalizes, the ABR threshold could (partly) normalize as well. These findings are consistent with those of Talero-Gutiérrez et al,²⁹ who found similar results after evaluation of 25 patients with severe to profound hearing loss.

Not unexpectedly, sensorineural hearing loss was more frequent in children in the NICU than in children referred from the well-baby clinics. Children in the NICU have increased incidences of potential risk factors associated with hearing loss, such as prematurity, low birth weight, receipt of ototoxic drugs.^{13,19} Being admitted to a NICU for more than 5 days is also a risk factor.¹⁸

The positive predictive value of the screening for SNHL is 54% for children referred from a well-baby clinic, versus 2% reported for the previously used Ewing/CAPAS screening.² Implementation of the UNHS resulted in a large decrease in proportions of false-positive findings. The frequency of OME (20%) is much lower than those reported for the Ewing/CAPAS screening (59% to 81%), because the child is tested at a younger age.

The median age for implementation of hearing aids, deemed necessary at any degree of hearing loss above 40 dB was 8 months (IQR 6 to 12 months). This is earlier than the 15 to 18 months resulting from application of the Ewing/CAPAS method.² For children with severe to profound hearing loss, implementation was even earlier, at 6 months. Hearing aids were not always implemented at

a young age for various reasons such as progressive hearing loss (where hearing aids were only needed at a later stage), parents preferring to delay hearing aids until their child was somewhat older, and the long waiting list for the fitting of hearing aids.

This study showed a much lower percentage of genetic hearing loss and hearing loss because of congenital infections than reported in the literature.^{25,30} In this study, infants were screened only when clinical indications for congenital infections or genetic hearing loss were present, whereas in some other studies all infants were screened. Additionally, not all parents gave consent for blood tests, and testing did not include virus isolation or molecular testing routinely. In most studies, cytomegalovirus is the major cause of hearing loss.^{31,32} We found a relatively high percentage of intrauterine rubella (1.5%), because of an epidemic of rubella infections within the nonvaccinated population in the Netherlands in 2004.^{33,34}

The universal neonatal hearing screening program is an enormous step forward in the screening and early treatment and intervention of children with hearing loss. The diagnostic process for cause of hearing loss needs to be improved to reduce the high proportion of children diagnosed with SNHL of unknown origin. ■

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