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Outcomes and limitations of hospital-based newborn hearing screening

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ABSTRACT

Objectives: Globally, newborn hearing screening (NHS) is variably incorporated into national healthcare systems. The authors reviewed the set-up and evolution process of a hospital-based NHS program in South Korea, where screening costs for low-income families are paid by the National Health Authority.
Methods: The NHS process for 13805 newborns delivered in a tertiary referral center of South Korea from 2005 through 2014 was reviewed. Hearing screening was conducted using automated auditory brainstem response (AABR); hearing loss was confirmed by auditory brainstem response for newborns who did not pass the screening test.
Results: The mean screening rate for hearing loss was 53.6% (7403 of 13805 newborns), which plateaued at 79.6% over time. Of the 14806 ears (7403 newborns), 1030 (7.0%) were assessed as "refer" on the first AABR, with 204 (1.4%) being assessed as "refer" on the second AABR. In hearing confirmation tests, 74 infants (1.0% of 7403 newborns) were diagnosed with hearing loss, including 13 infants (0.2%) with bilateral moderate to profound sensorineural hearing loss (SNHL). Hearing rehabilitation with long-term follow-up was confirmed in 11 infants.
Conclusions: In this hospital-based NHS program, the screening rate plateaued at ~50% when the National Health Authority was not involved, but increased to ~70% when the cost for low-income families was covered by the government. Among infants needing active hearing rehabilitation due to bilateral moderate to profound SNHL, 15% were lost to follow-up. These results demonstrate the need for a universal, mandatory NHS program to systematically register hearing-impaired infants within the government-sponsored public healthcare system.

1. Introduction

Hearing impairment is the most prevalent sensory deficit presenting at birth [1]. Because deficiencies in auditory input may lead to delayed language development and poor academic performance [2], the early detection of hearing loss and prompt intervention to restore auditory input are critical. Universal newborn hearing screening (NHS) is aimed at detecting congenital hearing loss at birth in all newborns and providing appropriate interventions to minimize the life-long handicap that arises from hearing deprivation [3].

Universal NHS is the first step in caring for hearing-impaired infants worldwide. According to the Early Hearing Detection and Intervention (EHDI) program outlined in the 2007 position statement of the Joint Committee on Infant Hearing (JCIH), all newborns should undergo a hearing screening test before they reach the age of 1 month. Furthermore, all newborns with a result of "refer" on the screening test should receive a confirmatory test to detect the presence of hearing loss before they reach 3 months of age, and all infants with confirmed hearing loss should receive intervention

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before the age of 6 months [4]. A good-quality, non-randomized study with a large birth cohort confirmed that newborns whose hearing loss had been identified through universal NHS were diagnosed and treated earlier, and thus had better language outcomes, at school age compared with those who had not been screened [3].

The prevalence of unilateral sensorineural hearing loss (SNHL) is 0.8–2.7 per 1000 newborns [5–8], with bilateral SNHL (≥40 dB) occurring in 1.33 per 1000 newborns [9]. The prevalence of congenital SNHL is higher in newborns with risk factors for hearing loss, such as prematurity and a history of care in a neonatal intensive care unit (NICU) [10]. In one study, the prevalence of SNHL in NICU newborns weighing >1500 g was higher than in newborns with very low birth weights (≤1500 g) and normal newborns (0.99, 0.3, and 0.1%, respectively) [11].

In a study on the prevalence of congenital SNHL, conducted in the Netherlands and based on a nationwide cohort of 2186 NICU newborns (mean gestational age: 28.5 weeks, mean birth weight: 1039 g) [12], the prevalence of SNHL was 3.2% (71/2186). In a recent report from Brazil on newborns in the NICU for >48 h, including 112 preterm newborns, the prevalence of SNHL was 1.5% (6/414) [13]. In our previous study on the prevalence of SNHL as a function of prematurity, 5 of 267 (1.9%) preterm newborns (mean gestational age: 29.4 weeks, mean birth weight: 520 g) had SNHL [14]. Taken together, although the study populations differed in gestational age, birth weight, and health status, these studies confirm that prematurity and a stay in the NICU are associated with higher incidences of SNHL.

Universal NHS has been implemented in many advanced countries as the main method for early detection of congenital hearing loss. However, in South Korea, universal NHS has yet to be incorporated into the nationwide public healthcare system. Since 2009, the National Health Authority has provided funds for hearing screening and confirmatory tests only for newborns in low-income families (<200% of the minimum cost of living) [15]. Coupons for the free testing of newborns have been issued to the relevant pregnant women by the National Health Authority. The coupons have been collected at each hospital conducting hearing screening and confirmatory tests, and the costs have been reimbursed by the Ministry of Health and Welfare.

This study was conducted at a tertiary referral center in South Korea, where the National Health Authority has partially paid the cost of NHS for low-income families. The aims of this study were to review how the NHS program has been adapted in health care system using data from 2005 through 2014 in South Korea, and to suggest the outcomes and limitations of hospital-based NHS. This study also analyzed the difference of hearing state between postnatal ward and NICU newborns.

2. Materials and methods

2.1. Subjects and hearing tests

This was a single-center retrospective cohort study of 13805 newborns born at Seoul National University Bundang Hospital (Seongnam, South Korea) from January 2005 to December 2014. The study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (IRB-B-1602-336-111).

Either the Madsen AccuScreen (GN Otometrics, Denmark) or the BERAphone MB11 (MAICO, Germany) was used to measure the automated auditory brainstem response (AABR) during the hearing screening test. AABR with stimulus of click (Madsen AccuScreen) or CE-Chirp (BERAphone MB11) of 35 dB nHL was performed before the infants were discharged from the hospital (24–48 h after birth). The results of the AABR were recorded as "refer" (further confirmatory tests needed) or "pass" (normal). Newborns in the former group were rescreened 2–4 weeks after the first AABR. Those with "refer" results in two consecutive screening tests, or having high risk factors for congenital hearing loss, underwent a hearing confirmatory test within 3 months of age.

The hearing threshold was confirmed based on the auditory brainstem response (ABR) (Navigator Pro, AEP; Natus, USA), and/or an auditory steady state response (ASSR) (Navigator Pro, MASTER I, II; Natus, USA), and/or otoacoustic emissions (OAE) (ILO292; Otodynamics Ltd., UK). The stimulus of ABR was an alternating click sound and tone burst (1, 3 kHz) and that of transient evoked OAE was an alternating click sound. The stimulus of distortion product OAE was two pure tones of different frequencies (f1, f2), and that of ASSR was frequency modulated pure tones with carrier frequency (0.5, 1, 2, 4 kHz) and high modulation rate (82–99 Hz). Hearing thresholds of <25, 26–40, 41–70, 71–90, and >91 dB were regarded as normal, mild, moderate, severe, and profound SNHL, respectively [16].

Rate of screening test implementation (screening rate) and the "refer" rate of the screening test over the 10-year study period were analyzed. The screening rate was determined per newborn, and the "refer" rate was determined per ear. The prevalence of hearing loss and bilateral moderate to profound SNHL, applied methods for hearing intervention, and follow-up status were also evaluated.

2.2. Comparison of hearing state between in postnatal ward and NICU newborns

Among the 13805 newborns, 10578 were on the postnatal ward and 3227 were in the NICU. To describe the difference in the hearing status between postnatal ward and NICU newborns, differences in screening rates, "refer" rates for each screening test, and the prevalence of hearing loss and bilateral moderate to profound SNHL were analyzed statistically.

According to the JCIH guideline, a family history of congenital hearing loss, *in utero* infection, craniofacial anomalies, hyperbilirubinemia requiring exchange transfusion, ototoxic medication gentamycin, tobramycin, and furosemide, etc), syndromes related to hearing loss (neurofibromatosis, Usher syndrome, Alport syndrome, Pendred syndrome, Waardenburg syndrome, Jervell and Lange-Nielson syndrome, etc), and assisted ventilation are risk factors for congenital hearing loss [6]. These perinatal conditions, together with an Apgar score at 1 min of 0–4, were considered as eight risk factors for congenital hearing loss. The frequency of the eight risk factors in the 74 infants (38 postnatal ward and 36 NICU newborns) with confirmed hearing loss was analyzed, and the frequencies in postnatal ward and NICU newborns were compared.

2.3. Statistical analysis

Data analysis was conducted using SPSS for Windows software (ver. 21.0; IBM Corp., USA). For bivariate comparisons, a χ^2 test or Fisher's exact test was used. All reported p values are two-sided; p values < 0.05 were considered to indicate statistical significance.

3. Results

3.1. Outcomes of hearing screening tests

Among the 13805 infants born at our center over the 10 years of the study, 7403 (14806 ears) were screened using AABR. The overall screening rate for hearing loss of 10 years was 53.6% (7403/13805). Fig. 1 shows the increasing trend in the screening rates from 2005 through 2014, with a maximum rate of 79.6% in 2011. The screening rates using the free coupons issued by the National Health