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Using click-evoked auditory brainstem response thresholds in infants to estimate the corresponding pure-tone audiometry thresholds in children referred from UNHS

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ABSTRACT

Objective: To examine whether behavioral pure-tone audiometry (PTA) thresholds in children can be accurately estimated from the corresponding infants' click-evoked auditory brainstem response (ABR) thresholds through a retrospective review of data from a universal newborn hearing screening (UNHS) program in Taiwan.
Method: According to medical records from Mackay Memorial Hospital, Taipei Hospital District, 45,450 newborns received hearing screening during January 1999–December 2011. Among these newborns, 104 (82, both ears; 22, one ear; total, 186 ears) received regular follow-up and were recruited as subjects. The relationship between infant click-evoked ABR thresholds and the corresponding child PTA thresholds was determined through Pearson correlation coefficient and linear regression analyses.
Results: The correlation coefficient between click-evoked ABR thresholds and behavioral PTA thresholds at the average of frequencies of 1–4 and 2–4 kHz was 0.76 and 0.76, respectively. Linear regression analysis showed that behavioral audiometry thresholds at the average of frequencies of 1–4 and 2–4 kHz were accurately estimated from click-evoked ABR thresholds in 57% and 58% children, respectively.
Conclusion: Click-evoked ABR testing is a reliable tool to cautiously estimate behavioral PTA thresholds at the average of frequencies of 1–4 and 2–4 kHz. For accurately performing hearing aid fitting and auditory rehabilitation in congenitally deaf infants, a combination of frequency-specific tone-burst ABR and click-evoked ABR should be used.

1. Introduction

Congenital hearing impairment has a considerable influence on the development of speech, learning, communication, social skills, and personality. Compared with people having normal hearing ability, those having even a mild degree or unilateral hearing impairment experience a noticeable difference in the quality of life [1]. The incidence of congenital unilateral and bilateral hearing impairments is approximately 2.1/1000 and 4.4/1000, respectively, according to a previous study in Taiwan [2]. Newborns with confirmed congenital hearing impairment should receive hearing aids and auditory rehabilitation within 6 months of birth, according to recommendations from the Joint Committee on Infant Hearing, Taiwan Health Promotion Administration, and Ministry of Health and Welfare [3]. Appropriate referral for early auditory rehabilitation as well as speech and language training can help congenitally deaf infants in developing comprehensive skills to communicate well in our study [4]. Comprehensive hearing assessment for diagnosing congenital hearing impairment in 0–6-month-old infants includes click-evoked auditory brainstem response (ABR), frequency-specific tone-burst ABR, otoacoustic emission (OAE), and 1-kHz tympanometry. Behavioral hearing tests, including behavioral observation audiometry (BOA) and visual reinforcement audiometry (VRA), can be performed at 6 months of age, following

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maturity of the neurological system. A confirmed diagnosis of congenital hearing impairment is based on the cross-check integration of both behavioral hearing test and objective hearing electrophysiological test results [5].

In Taiwan, hospitals performing confirmatory tests for congenital hearing impairment normally use click-evoked ABR or tone-burst ABR. However, a majority of these hospitals choose click-evoked ABR because tone-burst ABR is time-consuming and requires more technical personnel.

Gorga et al. [6] reported a high correlation between click-evoked ABR thresholds and behavioral PTA thresholds. In their study, the correlation coefficient (r) was 0.81 for the average of frequencies of 2–4 kHz in behavioral hearing tests. In addition, Van der Drift et al. [7] studied 209 ears with sensorineural hearing loss and revealed a reliable correlation between PTA thresholds and click-evoked ABR thresholds. They reported an r of 0.92 for PTA thresholds at the average of frequencies of 1–4 kHz. Hyde et al. [8] examined 713 children (1367 ears) with hearing loss to determine the accuracy of estimating their PTA thresholds at the ages of 3–8 years from their click-evoked ABR thresholds assessed at the ages of 3–12 months. Results showed that click-evoked ABR is suitable for estimating behavioral PTA thresholds at the average of frequencies of 2–4 kHz [8]. In a retrospective study, Gorga et al. [9] revealed that the r for PTA thresholds at the average of frequencies of 2–4-kHz is 0.94, indicating that click-evoked ABR is a reliable tool to evaluate behavioral hearing test thresholds at the average of frequencies of 2–4 kHz. Moreover, Baldwin et al. [10] reported an r of 0.90 between click-evoked ABR thresholds and PTA thresholds at the average of frequencies of 2–4 kHz.

These aforementioned consistent results indicate a promising estimation of PTA thresholds from click-evoked ABR thresholds in these infants and children with sensorineural hearing impairment. Another implication is that behavioral PTA thresholds can be cautiously estimated from click-evoked ABR thresholds alone, without the use of frequency-specific tone-burst ABR.

Frequency-specific tone-burst ABR testing is known to be more time consuming than is click-evoked ABR. Therefore, for practical reasons such as the workload involved in a busy UNHS program, some audiologists in Taiwan use only click-evoked ABR instead of tone-burst ABR. This study investigated the relationship between click-evoked ABR thresholds and behavioral PTA thresholds in congenital deaf children from the UNHS program in Taiwan.

2. Materials and methods

2.1. Subjects

This is a retrospective cohort study approved by the Mackay Memorial hospital's institutional review board (15MMHIS026), and the subjects were selected from the newborn hearing screening database of Taipei Mackay Memorial Hospital, Taiwan. From 1999 to 2004, we used OAE (Otodynamics) as a newborn hearing screening tool [11]. From 2005, automated ABR (AABR, Natus Algo 3) was used as the screening tool [12]. Between January 1999 and December 2011, 45,450 newborns underwent OAE or AABR screening. Of these newborns, 44,101 passed and 1349 failed. The ones who failed the initial OAE screening received a second diagnostic ABR re-test at 1 month of age. The ones who failed the initial AABR screening received a second AABR screening at 1 month of age. Consequently, 806 newborns passed the second screening and 415 failed; 128 were lost to follow-up. The 415 newborns who failed received comprehensive hearing test batteries, including tympanograms, click-evoked ABR, OAE, and behavioral hearing tests, between January 1999 and December 2014. The following were excluded from further analysis: 35 newborns with progressive hearing loss, fluctuating hearing loss, and conductive hearing loss (e.g., microtia, ear canal stenosis, and middle ear diseases); 94 newborns with bilateral AABR referral and 98 with unilateral referral who were lost to follow-up; and 84 newborns who passed the comprehensive hearing tests. Finally, 104 newborns with stationary sensorineural hearing impairment confirmed through click-evoked ABR tests received regular behavioral hearing assessment follow-ups and were recruited as our study subjects. Among the 104 subjects (59 males and 45 females), 82 had bilateral hearing impairment and 22 had unilateral hearing impairment. Thus, 186 ears (from 104 subjects) were included in the study (Fig. 1).

For the 104 subjects, the subjective and objective hearing test results from birth to 13 years of age were collected. The average age of the subjects who received click-evoked ABR and behavioral hearing tests was 2 months (range, 1–11 months) and 5 years 5 months (range, 3 years–13 years 10 months), respectively. We confirmed that the hearing impairment of these 104 subjects was stationary throughout the follow-up period.

2.2. Click-evoked ABR testing

The subjects who failed the initial AABR newborn hearing screening received a follow-up click-evoked ABR objective hearing test. The ABR machine used was Nicolet Spirit from 1999 to 2007 and Biologic from 2008 to 2011. Although two brands of ABR machines were used, the parameter setting was the same and is as follows: stimulus sound type, click; transducer, earphone; stimulus sound duration, 100 μs; repetition rate (RR), 27.7/s; and number of sweeps, 1500 times/s; additional settings were click stimulus with rarefaction polarity, 16-ms time window of analysis, and filter settings of 100–1500 Hz. The active channel was placed at the forehead (Fz) and the reference channel was placed at the bilateral mastoid areas (A1 and A2). The ground channel was placed between the eyebrows (Fpz). The impedance of all channels was less than 5 Kω, and the impedance difference between any two channels was less than 2 Kω. Before starting the test, the positions of all channels were checked. ABR wave interpretation was performed by an audiologist, according to at least twice-reproduced ABR morphology to determine the repeatability.

Newborns with click-evoked ABR thresholds worse than 30 dB nHL were considered hearing impaired and were enrolled in the study. They received several click-evoked ABR follow-ups between 0 and 11 months of age.

2.3. Behavioral hearing threshold measurement

The PTA machine, GSI 61, was used for behavioral hearing assessment. BOA or VRA was performed in babies were aged 6–36 months and PTA (to determine thresholds at frequencies of 0.5, 1, 2, and 4 KHz) in those older than 3 years.

2.4. Data analysis

We analyzed the data to determine the following: (1) the relationship between the click-evoked ABR thresholds and behavioral PTA thresholds at frequencies of 0.5, 1, 2, and 4 kHz in those older than 3 years; (2) the relationship between the click-evoked ABR thresholds and behavioral PTA thresholds at the average of frequencies of 1–4 kHz in those older than 3 years; and (3) the relationship between the click-evoked ABR thresholds and behavioral PTA thresholds at the average of frequencies of 2–4 kHz in those older than 3 years. MS Excel was used to record, calculate, and analyze the results. Pearson correlation coefficient was used to analyze the relationship between the click-evoked ABR thresholds and behavioral PTA thresholds. We used a linear regression model