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Reference values for neonatal BAEP and BA recordings using tubal insert phones

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1. Introduction

Hearing deficits are more common among neonates in neonatal intensive care units [1] and preterm neonates [2]. Good hearing is necessary for normal language development [3]. It is recommended that all infants should undergo hearing screening by the age of one month in order to enable early rehabilitation [4]. After initial screening, the diagnosis of a hearing deficit should be conducted using a reliable method and the results should be analysed using reference values calculated for preterm infants. In addition, the stimulation method should be taken into consideration. Thus, the aim of this study was to gather reference values for the recordings of brainstem auditory evoked potential (BAEP) and brainstem audiometry (BA) performed with Tubal Insert phone (TIP) stimulation.

BAEP and BA are considered the most accurate hearing evaluation methods because they can reliably detect and dissect peripheral and central (cochlear and brainstem) abnormalities [5]. There are also automated devices, for example, an a-ABR (automated auditory brainstem response), but they only give a rough pass or fail result, and the diagnostic reliability attained with these devices is not as accurate as that of a proper clinical neurophysiological evaluation. BA is also considered the most reliable test for hearing screening in high-risk neonates [6]. Small or preterm neonates have the greatest risk of hearing loss, especially as regards central defects, thus they are the category most in need of BAEP and BA examinations. For good clinical practice, normative reference values for neonatal BAEP and BA recordings are required with a sufficiently wide age distribution, including preterm babies. In previous reference value studies, most of the infants have been full term [7] or all the material on preterm infants has been excluded from the study [8].

BAEP and BA recordings can be made using either traditional headphones or tubal insert phones (TIPs) (Fig. 1). Several studies have concluded that insert phones are a useful method for delivering the stimuli [9–12]. Headphones may cause several problems in neonatal recording. Large headphones often cause restlessness in the child, which can lead to artefacts in the BAEP recordings. Headphones usually fit poorly on the child's head, which can result in leakage of the stimuli around the ear cushions [10]. In neonates especially, the pressure of the earphone can cause the ear canal to collapse [9]. With TIPs, the stimuli are delivered to the child's ear through a silicon tube and, as a consequence of this, the air conduction time prolongs the BAEP latencies. This simultaneously diminishes the effect of stimulation artefacts [11] that often obscure or distort the early BAEP waveforms I and II, when traditional headphones are used.

Because TIPs give a better definition of BAEP components I and II, and are more comfortable to use in small neonates (Fig. 1), the application of TIPs instead of headphones for neonatal BAEP and BA recordings was started 2002 in Turku University Hospital. However, specific reference values for neonatal BAEP or BA recordings with TIPs have not been published, although they are a prerequisite for achieving the full clinical benefit of the improved quality of the BAEP and BA responses. This is especially the case regarding the analysis of the function of the peripheral part of the auditory pathways reflected in BAEP components I and II. The aim of this study was to calculate novel and accurate BAEP and BA reference values specifically for TIP stimulation technique in a large group of neonates consisting mainly of preterm infants.

2. Materials and methods

2.1. Participants

At Turku University Hospital, 263 BAEP recordings were made in the department of clinical neurophysiology of infants born between 2002

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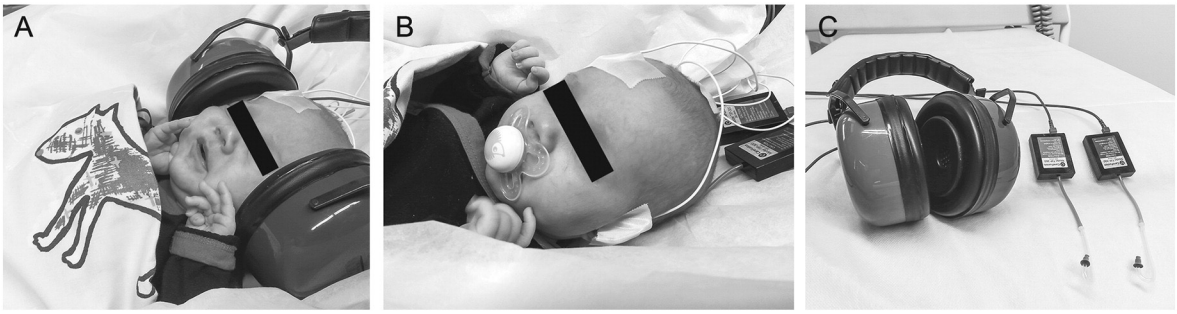

Fig. 1. Set-up for neonatal BAEP and BA recording performed with traditional headphones (A) and tubal insert earphones (B). Headphones and TIPs at a closer view (C). The length of the silicon tube in TIPs is 153 mm and in our department the length is monitored regularly.

and 2006 with tubal insert phones. This retrospective cross-sectional study was approved by the Hospital District of Southwest Finland Ethics Review Committee in 2010; as this was a register study, an undersigned consent from the parents was not required by the Committee.

For the calculation of the reference values, we included recordings of 177 neonates who had bilaterally repeatable BAEP and BA responses, which were normal according to the literature reference values [13]. The infants had to show normal hearing in later controls until the age of two years when their hearing was tested with a miniature audiometer (intensity 45 dB, frequency 3–4 kHz). The parameters in this device are constant and in this test, the infant sits in the parent's lap and the examiner stands behind the parent. A sound is then produced for both ears separately from a distance of 50 cm. If the infant turns his/her head or in other ways clearly reacts to the sound, the test is considered normal. The miniature audiometer test was done in free field stimulation settings, such as a doctor's office, during the 2-year follow-up visit. In addition to hearing, the neonatologist also evaluated whether or not the children could understand small, context-bound requests, could understand or use words, and had begun to use word combinations. The formation of the reference value database is presented in Fig. 2. The clinical characteristics of the infants are described in Table 1. Most neonates (82%) were preterm (birth weight ≤ 1500 g or GA ≤ 32 weeks) and most infants (89%) also underwent a BA recording, and their data were used to calculate reference values for the BA.

2.1.1. Procedure and equipment

BAEP and BA recordings were conducted in a quiet room by an expert in electrophysiological audiological testing at the Department of Clinical Neurophysiology. A paediatrician checked the eardrums and, if necessary, cleaned the ear canals before the recordings. All the children were either in a natural sleep condition or peacefully awake, usually after feeding. If the child was restless, a 20% glucose solution was given orally to soothe the infant. Each ear was tested separately. The BAEPs were recorded using an eight-channel Nicolet Viking IV instrument (Nicolet Biomedical Instruments, Madison, Wisconsin, USA). The recording electrodes were placed on the mastoids, the reference electrode at the vertex (Cz) anterior to the fontanel and the ground electrode on the forehead (Fp2'). Tubal insert earphones (Nicolet model TIP 300 Ohm) were used to deliver the air-conducted stimuli to the outer auditory canal, and were selected according to the size of the canal (Fig. 1). The length of the silicon tube was 153 mm.

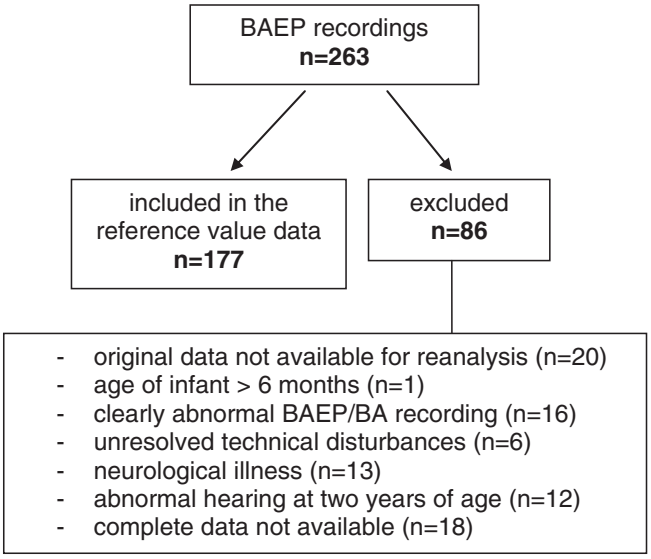

Fig. 2. The formation of the reference value database.

First, the infants underwent a BAEP recording. Broadband rarefaction click stimuli were given at the intensity of 85 dB nHL (repetition rate: 10.3 Hz). Simultaneously, the non-stimulated ear received masking white noise at 45 dB nHL. The earphones were calibrated using Sound Technology Spectra Pro software, an artificial ear of type B&K TYPE 4152 and a 2 cm^3 coupler. We used ± 3 dB as the accepted tolerance range, which is in accordance with the NHSP (Newborn hearing screening programme, England) recommendation. Calibration of the equipment is done yearly according to the accredited quality control system of our laboratory and the measurements have never exceeded the acceptable limits and have remained stable over the whole period. We set the low frequency filter (LFF; high pass filter) to 150 Hz and the high frequency filter (HFF; low pass filter) to 3 kHz. The amplifier sensitivity was 10 μV. 2000 responses were averaged at least twice. If a discernible BAEP response was not elicited, the stimulus level was raised to 95 dB nHL. After the recordings, an experienced technologist noted the peaks and the clinical neurophysiologist (SKJ) checked the peaks I, II, III, IV and V, and the troughs following peaks I and V.

After a successful BAEP recording, a BA was conducted in order to determine the click threshold of each ear separately. The recording was started at the intensity of 35 dB nHL (33.3 Hz) with a masking noise of 15 dB nHL in the non-stimulated ear. The normal procedure for BA testing in our hospital is that the intensity is increased in 10 dB

Table 1
Clinical characteristics of the infants forming the reference group.

	Reference value data	$n = 177$
Male/Female (n)	101/76	
Mean birth weight (g) (SD)	1570 (878)	
Birth weight range (g)	565–4370	
Birth weight ≤ 1500 g (n)	120 (68%)	
Mean gestational age (weeks) (SD)	30.6 (4.4)	
Gestational age range (weeks)	23–42	
Gestational age ≤ 32 weeks at birth (n)	124 (70%)	
≤1500 g or ≤32 weeks at birth (n)	146 (82%)	
Small for gestational age (n)	53 (30%)	
Mean post-term age at the time of BAEP Recordings (months) (range)	1.1 (−1.2–6.6)	