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Auditory brainstem responses to broad-band chirps: Amplitude growth functions in sedated and anaesthetised infants

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ABSTRACT

Objective: Recently an optimized broad-band chirp stimulus has been proposed for the objective estimation of hearing thresholds with auditory brainstem responses (ABRs). Several studies have demonstrated that this stimulus, compensating for the travelling wave delay of the frequency components of a click stimulus at the basilar membrane, evokes larger ABR amplitudes in adults. This study analyses the amplitude of chirp-evoked ABRs recorded in infants below 48 month of age under clinical conditions and compares these results with literature data.

Methods: Chirp-evoked ABR recordings in 46 infants under chloral hydrate sedation or general anaesthesia were analysed retrospectively. The amplitude of the wave V was measured as a function of the stimulus intensity. To compare ABR amplitudes across infants with different hearing losses, the stimulus intensity was readjusted to the subjects' individual physiological threshold in dB SL (sensation level). Individual wave V amplitudes were plotted against stimulus intensity and individual amplitude growth functions were calculated. To investigate the maturation of chirp-evoked ABR, data from infants below and above 18 months of age were analysed separately.

Results: Chirp-evoked ABR amplitudes in both age groups were larger than the click-evoked ABR amplitudes in young infants from the literature. Amplitudes of chirp-evoked ABR in infants above 18 months of age were not substantially smaller than those reported for normal hearing adults. Amplitudes recorded in infants below 18 months were significantly smaller than those in infants above 18 months. A significant difference between chirp-evoked ABR amplitudes recorded in sedation or under general anaesthesia was not found.

Conclusions: The higher amplitudes of ABR elicited by a broadband chirp stimulus allow for a reduction of the recording time in young infants.

1. Introduction

Recordings of auditory brainstem responses (ABR) are widely used to evaluate the audiological status of infants who failed the newborn hearing screening or who have developed hearing impairment in the postnatal period. Beyond that the ABR is a reliable tool to assess the neurologic integrity of the auditory brainstem and to demonstrate the infants' normal neurologic development [1–4]. Several studies have demonstrated that the applicability of the ABR for the objective estimation of the hearing threshold as well as for neurologic purposes critically depends on the quality of the recording [5–7]. This quality is mostly influenced by two independent factors: (1) the residual EEG (electroencephalogram) noise level of the recording and (2) the amplitude of the evoked potentials. A reduced residual EEG noise level and increased response amplitude may both contribute to a more reliable estimate of the infants' individual hearing threshold and to a more accurate labelling of peak latency and amplitude.

The residual noise of an ABR recording after a particular recording time is mainly determined by the level of the physiological background noise and can be controlled to a certain extent by filtering the EEG and by the number of averages. The individual EEG amplitude is the most detrimental parameter of the averaging process. It depends on the subject's state of arousal. ABR recordings in young infants are therefore conducted mostly in natural sleep, in sedation or under general anaesthesia [2,8–10].

The ABR amplitudes depend on individual physiological parameters as for instance the individual hearing level and the maturational status of the infant and on stimulus parameters as for instance stimulus type (click, tone burst) and stimulus repetition

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rate. Although it is common practice for more than 30 years to evoke ABR by a 100-μs wide click pulse or by short tone pips, efforts have been made to construct stimuli which can evoke larger response amplitudes. Dau et al. [11] described a chirp stimulus for the recording of auditory brainstem responses, compensating for the travelling wave delay of the frequency components of a click stimulus at the basilar membrane. They argued that such a compensation results in a higher temporal synchronization of the neural structures contributing to the ABR, producing remarkably large response amplitudes. Recently, Elberling et al. [12,13] published a series of studies, describing optimized chirp stimuli for the recording of ABR and auditory steady-state responses (ASSR). As a result of their findings, the so-called 'CE-chirp' was implemented in a clinical ABR recording system. Although the new stimulus was widely evaluated in normal-hearing adults during the intense process of optimization [14,15] clinical data from chirp-evoked ABR in young infants have not yet been published.

Jiang et al. [16] demonstrated that during the first three years after birth wave V amplitude of click-evoked ABR in infants depends strongly upon age, increasing as a function of age accompanied by a shortening of the ABR wave latencies and interpeak intervals [17,18]. It is likely that a similar maturational characteristic is observed in chirp-evoked ABR.

The aim of the present study is twofold: on the one hand, this study analyses the amplitude and the amplitude growth function of chirp-evoked ABRs in young infants under clinical conditions and compares these data with literature data from an adult population and from click-evoked infant ABRs. On the other hand, the influence of maturation on the chirp-evoked ABR in an age range between 1 and 48 months is evaluated.

2. Methods

2.1. Subjects

Archived ABR data from infants who underwent chirp-evoked ABR measurements for evaluation of hearing loss at the Department of Otorhinolaryngology of the University Hospital Magdeburg in 2011 were analysed retrospectively. From these records all infants below the age of 48 months who underwent the ABR recording under chloral hydrate sedation or general anaesthesia were included in this study. From the 46 infants who fulfilled these criteria 26 were male and 20 were female. In 25 infants ABRs were recorded in sleep after sedation with chloral hydrate (50 mg/kg body weight). In 21 infants ABRs were recorded in the operating room under general anaesthesia with Propofol. The protocol used in this retrospective study was in accordance with the ethical guidelines of the Medical Faculty of the University of Magdeburg, where the study was conducted. The procedures are in agreement with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

2.2. Recording parameters

All data were collected with a commercial ABR software module (Interacoustics A/S, Assens, Denmark, Version 4.2.0.8) running on an Interacoustics Eclipse EP25 platform (Hardware Version 3.4.4). Ag/AgCl-electrodes were placed at the vertex (non-inverting+) and both earlobes (inverting−) with a ground electrode at the forehead. Impedances were kept below 5 kΩ. The EEG activity was amplified by 80 dB, band pass filtered from 100 Hz to 1500 Hz using filter slopes of 12 dB/octaves, and digitised with a 16-bit resolution. An artefact rejection level of ±40 μV was applied. Consecutive sweeps of 15-ms duration starting at stimulus onset were averaged. According to Elberling et al. [15] data acquisition was stopped automatically, when the estimated residual EEG-noise level of the recording achieved an amplitude below 40 nV. The residual EEG-noise amplitude in the averaged ABR waveform was estimated online, based on the algorithm described by Elberling and Don [19], and Don et al. [5,6]. For each subject individual response levels for both ears were determined, using a bracketing algorithm starting at a stimulus level of 50 dB nHL with a step size of 10 dB.

2.3. Stimuli

Acoustic stimuli were presented at a repetition rate of 40/s through ER-3A earphones. The commercial ABR system used in this study provides a broadband chirp stimulus with a flat amplitude spectrum between 350 Hz and 11,300 Hz ('CE-chirp') which is described in detail by Elberling et al. [12]. Fig. 1 depicts the time course of the electrical voltage at the earphone, measured with an Agilent X 2004A digital storage oscilloscope. Fig. 2 shows amplitude spectra of the chirp, calculated by Fast Fourier Transform from the electrical signal shown in Fig. 1 and from the sound pressure generated by the ER-3A earphone which was recorded from the output of a sound level meter (Bruel & Kjaer 2250) connected with an occluded ear simulator (Bruel & Kjaer 4157). The contralateral ear was masked with noise at 30 dB below the ipsilateral stimulus level.

2.4. Data analysis

Two independent experts evaluated all EEG recordings. Since the study aims to describe amplitude growth functions of chirp evoked ABR, the wave V peak-to-trough amplitude of each recording was measured as a function of the stimulus intensity [13,14].

To investigate the influence of maturation on the chirp-evoked ABR amplitude, data from infants with ages between 1 and 18 months and between 19 and 48 months were divided into two age groups with 23 infants, respectively. The cut-off age of 18 months was derived from the findings published 1989 by Gorga et al. [17], stating a stabilisation of wave V latency in infants above 18 months.

In order to compare the data across infants with different hearing losses, the stimulus intensity was readjusted to the subjects' individual physiological threshold in dB SL (sensation level) as proposed by Picton et al. [20]. Physiological ABR thresholds were determined as the lowest intensity at which no significant response was detected and were labelled "0 dB SL". As

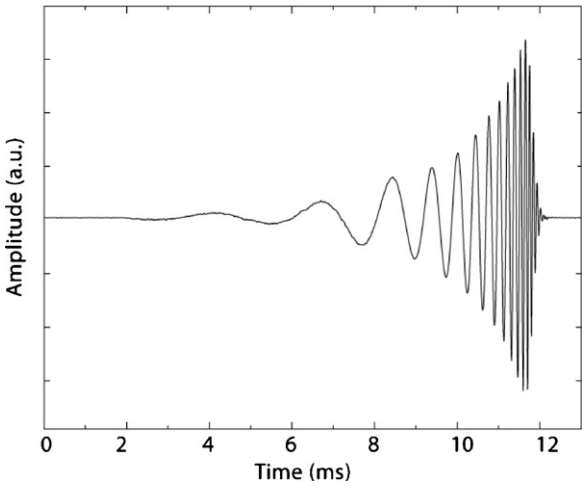

Fig. 1. Broadband chirp ('CE-chirp' [12]) used in this study. The graph shows the time course of the electrical voltage at the ER-3A earphone, measured with an Agilent X 2004A digital storage oscilloscope and plotted in arbitrary units.