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The properties of spontaneous and evoked acoustic emissions in neonates and children: a preliminary report*

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Summary. Evoked acoustic emissions (EAEs) and spontaneous acoustic emissions (SAEs) recordings hold some promise as a fast, objective and non-invasive audiological procedure, especially in children. However, accurate interpretation in the emission response must be based on the basic properties of the emissions present in a younger age group. In so doing, the properties of emissions were investigated in 49 ears from 26 children, whose ages varied between 2 days and 10 years. EAEs could be recorded in all normal ears, but the incidence of long-duration EAEs decreased with age. There were no statistically significant variations in recording the EAEs detection threshold with age. The incidence of SAEs also decreased with age.

Key words: Spontaneous acoustic emission – Evoked acoustic emission – Audiometric test – Normative data – Children

Introduction

Gold [5], in 1948, proposed the existence of a mechanical positive feedback system located within the cochlea which increased the basilar membrane movement and predicted the presence of evoked acoustic emissions (EAEs) in the external ear canal. Since the discovery of EAEs from the human ear [8], many researchers have investigated this phenomenon as a possible basis for a clinical test of inner ear function. Screening for auditory dysfunction in infants is probably one of the major applications of EAEs [4, 7]. However, accurate interpretation of changes in the EAEs response in children must be based on a knowledge of its intrinsic variability. The aim of this paper was to define some basic (normative) features of EAEs responses in a healthy population of neonates and infants.

Materials and methods

Recordings of acoustic emissions. Because the acoustic probe, stimulus generation, signal processing and EAE identification have been previously described in detail [1, 3], only a brief account will be presented here. EAEs were recorded with a small acoustic probe incorporating a miniature microphone (Knowles BT1751) and a small earphone (Knowles BK2615). The probe was sealed into the external ear canal of the children using an impedance probe protector. All recordings were done with the children reclined in a double-walled, sound-treated booth. Neonates were swalled and placed in a bassinet. Recordings were done as the children slept after feeding.

The acoustic stimuli were rarefaction clicks delivered at a repetition rate of 21/s. EAEs was amplified ($\times$ 5000), band-pass filtered (high-pass: 250 Hz, 16 dB per octave; low-pass: 8 kHz, 6 dB per octave), sampled within a time window of 30 ms that started 7 ms after the stimulus onset and averaged in the time domain over 512 repetitions. The averaged signal was fed into a Hewlett-Packard 3661A frequency analyzer for fast Fourier-transform analysis. EAEs were recorded at various stimulus intensities ranging from 30 dBHL to the detection threshold in 5 dB steps. The thresholds of the EAEs were defined using a visual detection threshold criteria in both time and frequency domains.

For spontaneous acoustic emission (SAEs) recordings, the signal was amplified ($\times 10^4$), high-pass filtered (250 Hz, 16 dB per octave), and fed into the signal analyzer. The frequency resolution was 37.5 Hz. The spectrum was displayed on a linear scale. As previously described [9], SAEs were defined as narrow-band acoustic signals, clearly above the noise floor of the measuring system that could be replicated on at least two separate averages.

Patients. Acoustic responses were recorded on a total of 49 ears (26 children). The ages of the tested children varied between 2 days and 10 years. Three groups of children were studied and in-

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Table 1. Main parameters of the three groups of tested children: age, sex, numbers of ears, numbers of subjects

	Group I	Group II	Group III
Age	Below 18 months	1.5–5 years	5–10 years
Males	6	4	4
Females	5	3	4
Number of ears	21	12	16

Table 2. Main properties of evoked acoustic emissions (EAEs) in three age-based groups of children

	Group I	Group II	Group III
Age	Below 18 months	1.5–5 years	5–10 years
Duration of EAEs			
short (below 20 ms)	20%	33%	42%
long (more 20 ms)	80%	67%	58%
Detection-threshold			
Mean (db HL)	2	−0.5	0
Standard deviation	6	4	5
Incidence of SAEs (%)	66.7	58.4	50

cluded normal term infants. Table 1 indicates the main parameters of the three groups of tested children: age, sex, numbers of ears, numbers of subjects. Informed consent for the study was obtained from the parents. All subjects were healthy and children considered as high risk with regard to hearing, having middle ear pathology, or having current upper respiratory disease were excluded from the study.

For all children, a conventional auditory brainstem-evoked response (ABR) threshold was determined. The threshold was determined on wave V measurements. ABR threshold was determined at an 80 dB HL level, and replications in 10-dB decrements from 80 dB HL down to the detection threshold. All children had ABR thresholds equal to or below 30 dB HL. Statistical analysis of these data was done by analysis of variance and the level of significance was a P value of 0.05 or less.

Results

Evoked acoustic response

Click stimuli elicited EAEs from 100% of the ears. Across ears, EAEs varied in duration, detection threshold and frequency spectrum. Seventeen (80%) ears demonstrated long-duration (more than 20 ms) EAEs in the group I infants (2–18 months old). This incidence decreased with age. Table 2 summarizes the main characteristics of EAEs from the three groups. The mean EAE detection threshold also varied with age. However, there were no statistical difference between these values.

Two distinct patterns of EAEs were identified with respect to spectra. All EAEs exhibited a broadband spectrum with a frequency maxima near 1.45 kHz. Sixty-one percent of the tested ears demonstrated several narrowband frequency peaks ranging from 1 to 11, with an average of 3.5/ear. Narrowband peaks were only observed in long-duration EAEs. Short-duration EAEs were generally broadly tuned and devoid of narrowband peaks.

Spontaneous acoustic response

SAEs were present in 14 of the 21 ears tested in group I (less than 18 months old). This incidence decreased from 66.7% to 50% in group III. These data are summarized in Table 2. The mean number of emissions per ear was 2.9.

Discussion

A previously pointed out [4, 7], EAEs recordings hold great promise for the objective demonstration of cochlear pathology in children. Our present study defines some basic features of EAEs and SAEs in a group of normally hearing children and could permit accurate interpretation of changes in otoacoustic emissions responses in pediatric deafness.

Our present findings show in a group of children with age varying from 2 days to 10 years that *(1)* EAEs can be recorded in all normal ears; *(2)* the incidence of long-duration EAEs decreased with age; *(3)* there were no statistically significant variations in regard to EAEs detection thresholds with age; *(4)* the incidence of SAEs decreased with age.

The incidence of EAEs in normally hearing children was 100%. This incidence is in accordance with previous reports involving adults [2, 6]. The incidence of long-duration EAEs varied with age and its reported occurrence has varied from 80% [9] to 67% [1]. The detection threshold of EAEs seems to be one of the main parameters that is clinically applicable. In our present study, the mean EAEs detection threshold did not vary significantly with age, although the EAEs detection level in all cases was below 10 dB HL. Similar data have been reported in adults [1].

The incidence of SAEs in the children tested varied from 66% in our group I subjects to 50% in group III. Strickland et al. [11] were the first to report the incidence of SAEs in children. This incidence was 32%, but children ranged in age from 5 years to 12 years, with a mean value of 9 years. In adults, the incidence of SAEs has varied from 26% [12] to 42% [10]. Our present findings indicate that the main difference in

acoustic emission properties between adults and children seems to be the incidence of SAEs.

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