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Are auditory steady-state responses a good tool prior to pediatric cochlear implantation?

Roberto Miquelino de Oliveira Beck [a,*], Signe Schuster Grasel [a,1], Henrique Faria Ramos [b,2], Edigar Rezende de Almeida [a,1], Robinson Koji Tsuji [a,1], Ricardo Ferreira Bento [a,1], Rubens de Brito [a,1]

[a] University of Sao Paulo School of Medicine, 255, Dr. Enéas de Carvalho Aguiar Street, Sao Paulo, SP, 05403-000, Brazil
[b] University of Espirito Santo (UFES), 514, Fernando Ferrari Avenue—Goiabeiras, Vitória, ES, 29075-910, Brazil

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ABSTRACT

Introduction: ASSR allow frequency-specific evaluation in intensities up to 120 dB HL and detection of residual hearing in patients with severe-to-profound hearing loss.
Aim: to compare ASSR thresholds and behavioral test results in children with suspected severe-to-profound hearing loss.
Methods: Cross sectional study to compare ASSR and behavioral responses (VRA or audiometry) in 63 pediatric cochlear implant candidates (126 ears) aged between 6 and 72 months. We included children with normal otomicroscopy, absent responses to click-ABR and otoaccoustic emissions. We excluded children with inner ear malformations, auditory neuropathy spectrum disorder or who did not complete VRA or achieve EEG noise < 30 nV during the ASSR test. Air-conduction ASSR stimuli were continuous sinusoidal tones presented at 0.5, 1, 2 and 4 kHz starting at 110 dB HL. Behavioral thresholds were acquired with warble tones presented at 0.5, 1, 2 and 4 kHz in each ear through insert or head phones at maximum presentation level of 120 dB HL.
Results: Behavioral thresholds were obtained in 36.7% (185/504) of all frequencies in all subjects, 9% in intensities >110 dB HL. Among 504 ASSR measurements, 53 thresholds were obtained (10.5%). Overall 89.5% of the tested frequencies did not show any response at 110 dB HL. Most responses were at 500 Hz. Mean differences between behavioral and ASSR thresholds varied from 0.09 to 8.94 dB. Twenty-seven comparisons of behavioral and ASSR thresholds were obtained: 12 at 0.5 kHz, 9 at 1 kHz, 5 at 2 kHz and 1 at 4 kHz. Absent responses were observed in both tests in 38.1% at 0.5 kHz, 52.4% at 1 kHz, 74.6% at 2 kHz and 81.0% at 4 kHz. Specificity was > 90% at 1, 2 and 4 kHz. In ears with no behavioral response at 120 dB HL all ASSR thresholds were in the profound hearing loss range, 90% of them were ≥110 dB HL.
Conclusion: Among 63 pediatric CI candidates, absent responses to high-intensity ASSR was the major finding (specificity > 90%) predicting behavioral thresholds in the profound hearing loss range. These findings can be helpful to confirm the decision for cochlear implantation.

1. Introduction

Newborn hearing screening and early identification of hearing loss show~~s~~ clear benefits. So diagnostic evaluation should follow as soon as possible to provide hearing-impaired children with adequate amplification and follow-up. Children with mild-to-moderate hearing loss may benefit from hearing aids; those with severe-to-profound hearing loss are candidates for cochlear implantation (CI) [1–4].

Behavioral hearing tests such as visual reinforcement audiometry (VRA) and play-audiometry provide accurate information in children above the age of 6 months but can be unreliable for younger children or those with developmental delay or visual disorders [5–7]. Therefore, physiologic hearing measures are essential to confirm hearing loss.

Auditory evoked potentials permit separate ear-and frequency-specific hearing evaluation. The most widely used procedure is the click and tone burst Auditory Brainstem Response (ABR). However, due to the transient nature of stimuli employed to evoke ABR, in clinical practice the maximum presentation level usually does not

* Corresponding author. Tel.: +55 11 26617183/+55 11 981526884.
E-mail address: robertomobeck@gmail.com (R.M.d.O. Beck).
[1] Tel.: +55 11 26617183.
[2] Tel.: +55 27 4009 2200.

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exceed 95 dB HL to avoid saturation. Absent ABR is consistent with significant hearing impairment but cannot distinguish between severe and profound hearing loss [8,9].

Auditory steady-state responses (ASSR) allow frequency-specific stimulation at intensities up to 120 dB HL. The investigation of residual hearing in young children with objective measures contributes to appropriate selection and fitting of hearing aids before surgery and to confirm profound hearing loss [10].

Although Gorga et al., Small et al., and Picton et al. [11–13] observed artifactual responses to high-intensity ASSR, especially at 500 and 1000 Hz, these issues were corrected for the MASTER system [13].

Nevertheless, few studies used ASSR to evaluate children with severe-to-profound hearing loss since 2004. Swanepoel and Hugo [14] studied 15 children aged between 10 and 60 months with suspected severe-to-profound hearing loss. They tested four frequencies (0.5, 1, 2 and 4 kHz) bilaterally in intensities between 120 and 128 dB HL. They found that 87% of thresholds measured were at intensities equal or higher than 100 dB HL and 47% were at 115 dB HL or higher.

Swanepoel et al. tested 10 children between 10 and 15 years with severe-to-profound hearing loss and found close relation between pure-tone thresholds and recorded ASSR thresholds [15].

In adults, comparing ASSR and warble tone audiometry, Ramos et al. [16] found high sensitivity and specificity for ASSR. Some previous data from our group showed no artifactual responses among children in intensities up to 110 dB HL [17,18]. In this study we showed that ASSR underestimated behavioral hearing thresholds obtained by instruments in 7/42 pediatric patients [18]. So there is a clear need for more data to compare high intensity ASSR with behavioral pure tone tests among the pediatric population.

The objective of this study is to compare ASSR thresholds and behavioral test results at 500, 1000, 2000 and 4000 Hz in young children prior to cochlear implantation.

2. Methods

2.1. Subjects

The research was approved by the Ethics Committee of the University of São Paulo School of Medicine (41225/2012). Sixty-three pediatric CI candidates (126 ears), aged between 6 and 72 months (mean 29.14 ± 13.5 months, 30 girls), were enrolled in the study. All parents signed the informed consent according to the Helsinki's Declaration.

Inclusion criteria were: normal otomicroscopy findings, absent otoaccoustic emissions, absent click air-conduction ABR at 90 dB HL and bone conduction at 55 dB HL. We excluded children with vestibular or cochlear malformations seen on MRI or CT, such as enlarged vestibular aqueduct or cochlear nerve deficiency. Subjects with auditory neuropathy spectrum disorder or who did not complete the behavioral evaluation or achieve electroencephalographic noise under 30 nanovolts (nV) during the ASSR test were also excluded.

2.2. Methods

2.2.1. Visual reinforcement audiometry (VRA)/pure tone audiometry (PTA)

Two audiologists conducted VRA in a double-walled, sound attenuated room using the Interacoustics AC33 clinical audiometer (Assens, Denmark). Behavioral air conduction thresholds were obtained with warble tones presented at 500, 1000, 2000 and 4000 Hz in each ear through ER-tone 5A (Etymotic Research, Elk Grove Village, IL) or TDH-39 (Telephonics Corporation Huntington, NY) calibrated according to ISO 389-2 and 389-1, respectively.

Threshold was obtained using a 10 dB down, 5 dB up technique with the upper limit at 120 dB HL for each frequency.

The investigators judged the responses, which were considered consistent if positive in at least 2 of 3 attempts.

For older children, over 3 years old, traditional pure tone audiometry was performed to obtain thresholds.

All but 2 patients were evaluated after using hearing aids for at least 6 months.

2.2.2. Auditory steady-state responses

In our hospital all pediatric ABR tests are performed under light general anesthesia (Sevofluorane). The ASSR procedure was carried out during routine evaluation after otomicroscopy, click ABR and otoaccoustic emissions. Each child performed all tests in one session.

2.2.2.1. ASSR stimulus. The multiple auditory steady-state response (MASTER) software (version 2.04.i00) running on the Bio-Logic Navigator Pro System (Natus Medical Incorporated, San Carlos, CA) was used for the ASSR measurements.

The stimuli used to evoke air-conduction ASSR were continuous sinusoidal tones modulated 100% in exponential amplitude and 20% in frequency. These sinusoidal tones were presented through ER-3A insert earphones (Etymotic Research, Elk Grove Village, IL). The carrier frequencies of 500, 1000, 2000 and 4000 Hz were tested, modulated at 66.797 Hz in the left ear and 69.141 in the right ear. The stimulation was dichotic for a single frequency in each run [12]. Maximum presentation level was 110 dB HL for all frequencies.

Air-conduction stimuli were calibrated in dB HL, according to ANSI S3.6-1996 standard, using a Quest Electronics model 1700 sound level meter with Brüel & Kjær DB0138 2 cm^3 coupler.

2.2.2.2. ASSR recordings. Recordings occurred in a sound-attenuated, electrically shielded room. The same physician, without prior knowledge of the behavioral thresholds, performed all tests.

Surface electrodes were positioned at high forehead (Fz, non-inverting), nape (Oz, inverting) and on the right shoulder (Pz, ground). All electrode impedances were less than 5 k Ω.

Electroencephalographic activity was filtered using a band-pass filter of 30 to 300 Hz and amplified by a gain of 10,000. The responses were recorded in epochs lasting 0.8533 s. Sixteen data epochs were collected and linked together to form one sweep with an overall duration of 13.653 s.

Data epochs containing excessive noise were excluded when amplitudes exceeded artifact rejection level of 60 μV. Epochs that contained electrophysiological activity exceeding 90 nV were rejected [17]. The maximum amount of sweeps was determined according to the pre-set specifications of the equipment: 10 sweeps in intensities above 100 dB HL, 12 sweeps between 90 and 99 dB HL and 18 sweeps between 80 and 89 dB HL.

Once completed each sweep was averaged in the time domain and subsequently submitted to a fast Fourier transform. The resulting amplitude spectrum enabled steady-state responses to be analyzed in the frequency domain. The software determined whether the response amplitude at the modulation frequency was significantly different from the mean amplitude of the electroencephalographic background noise in adjacent frequencies and analyzed the frequency spectrum automatically. The significance of the signal-to-noise ratio was assessed by F-ratio with a confidence interval of 95% for each sweep collected. A response was considered to be "present" when the F-ratio was significant at a level of $p < 0.05$, for at least five consecutive sweeps [5]. Consequently, a "no-response" was considered when the signal-to-noise ratio did not reach significance ($p < 0.05$) after the maximum number of sweeps.