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CORRELATION OF ASSR HEARING THRESHOLDS WITH ABR HEARING THRESHOLDS IN CHILDREN

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

Alexandra Vasileiou[1ABCE], Maragoudakis Pavlos[1BD], Tzagaroulakis Antonios[1B], Xenellis Ioannis[1CE], Petros V. Vlastarakos[2EF], Thomas P. Nikolopoulos[1ABCE]

[1] ENT Department of the National and Kapodistrian University of Athens, Attikon University Hospital, Athens, Greece
[2] ENT Department, MITERA Paediatric Infirmary, Athens, Greece

Corresponding author: Thomas Nikolopoulos, E-mail address: nikolop@med.uoa.gr, Address: 125 Anakous street, Athens 14342, Greece

Abstract

Background: Hearing assessment in neonates, or in older children/teenagers with special needs, is very challenging since a pure tone audiogram is not possible due to lack of co-operation and click-ABRs are not frequency specific.

Objectives: To assess the value of auditory steady-state responses (ASSRs) in neonates or in uncooperative children/teenagers and correlate the hearing thresholds derived from them with those derived from ABR.

Subjects and Methods: Using ABR and ASSR, the hearing thresholds of 119 children too young to perform behavioral audiometry, and older children or teenagers with special needs (who were unable or unwilling to perform a pure tone audiogram), were assessed. The age range was 1 month to 18 years old with a mean age of 2.7 years and median of 2.3 years; the large majority (106 or 89%) were younger than 5 years.

Results: ASSR was found to be a valuable and objective method for hearing assessment as a strong correlation between ABR-derived and ASSR-derived thresholds was found for all frequencies (500, 1000, 2000, and 4000 Hz) with Spearman rank correlation coefficients ranging from 0.83 to 0.87 and high statistical significance ($p<0.0001$).

Conclusion: The reliability of ASSR is supported by the results of the present study which suggest that there is a strong correlation between ASSR and ABR thresholds even at a frequency of 500 Hz.

Keywords: ASSR • ABR • hearing loss • deafness • thresholds • hearing • children

CORRELACIÓN ENTRE LOS UMBRALES DE AUDICIÓN DE LOS POTENCIALES EVOCADOS AUDITIVOS DE ESTADO ESTABLE Y LOS UMBRALES DE AUDICIÓN DE LOS POTENCIALES EVOCADOS AUDITIVOS DE TRONCO CEREBRAL EN NIÑOS

Resumen

Introducción: La valoración de la audición en neonatos o niños mayores / adolescentes con discapacidad es muy difícil ya que no es posible realizar una audiometría total dada la falta de colaboración y la prueba de potenciales auditivos de tronco cerebral evocados con clicks (PEATC) no es especifica en frecuencia.

Objetivo: Valoración de los potenciales evocados auditivos de estado estable (PEAEE) en neonatos o niños y jóvenes no colaborativos y correlación entre los umbrales de audición obtenidos y los umbrales obtenidos en base a los PEATC.

Material y métodos: Por medio de PEATC y PEAEE se evaluaron los umbrales de audición en 119 niños demasiado pequeños como para poder realizar una audiometría conductual, así como niños mayores o adolescentes con discapacidad (que no eran capaces o no querían someterse a la prueba de audiometría tonal). El rango de edades comprendía entre 1 mes hasta 18 años, con una media de 2,7 años y una mediana de 2,3 años; la gran mayoría (106, es decir el 89%) tenía menos de 5 años.

Resultados: Se comprobó que PEAEE es un método valioso y objetivo para valorar la audición, ya que se observó una fuerte correlación entre los umbrales obtenidos con las pruebas PEATC y las pruebas PEAEE para todas las frecuencias (500, 1000, 2000 y 4000 Hz) con un coeficiente de correlación de Spearman de entre 0,83 y 0,87, y una alta relevancia estadística ($p <0,0001$).

Conclusiones: Los resultados del presente estudio confirman la credibilidad de PEAEE e indican una fuerte correlación entre los umbrales PEAEE y PEATC, incluso en la frecuencia de 500 Hz.

Palabras clave: PEAEE • PEATC • hipoacusia • sordera • umbrales • audición • niños

КОРРЕЛЯЦИЯ ПОРОГОВ СЛЫШИМОСТИ СЛУХОВЫХ СТАЦИОНАРНЫХ ВЫЗВАННЫХ ПОТЕНЦИАЛОВ С ПОРОГАМИ СЛЫШИМОСТИ СТВОЛОВЫХ СЛУХОВЫХ ВЫЗВАННЫХ ПОТЕНЦИАЛОВ У ДЕТЕЙ

Абстракт

Введение: ценка слуха у новорожденных или детей старшего старших возраста / подростков, нуждающихся в особой опеке, является очень сложной задачей, потому что проведение тональной аудиометрии не представляется возможным в связи с отсутствием взаимодействия, а измерение стволовых слуховых вызванных потенциалов (ABR) не позволяют провести частотно-специфическую оценку потери слуха.

Цель: Оценка значения слуховых стационарных вызванных потенциалов (ASSR) у новорожденных или у детей и молодежи с отсутствием взаимодействия, а также корреляция полученных порогов слышимости с порогами слышимости, полученными в результате ABR.

Материал и методы: с помощью ABR и ASSR была выполнена оценка порогов слышимости у 119 детей, возраст которых не позволял провести поведенческую аудиометрию, а также детей старшего возраста или подростков, нуждающихся в особой опеке (которые не могли или отказывались проходить исследования методом тональной аудиометрии). Возрастной диапазон составил от 1 месяца до 18 лет, средний возраст – 2,7 года, медиана – 2,3 года; преобладающее большинство (106, то есть 89%) детей было младше 5 лет.

Результаты: Установлено, что ASSR является ценным и объективным методом оценки слуха, поскольку была обнаружена значительная корреляция порогов слышимости, полученных в результате проведения тестов ABR и ASSR для всех частот (500, 1000, 2000 и 4000 Гц), с коэффициентами ранговой корреляции Спирмена от 0,83 до 0,87 и высокой статистической значимостью (p <0,0001).

Выводы: Результаты настоящего исследования подтверждают достоверность ASSR и показывают высокую корреляцию между порогами ASSR и ABR даже в случае частоты 500 Гц.

Ключевые слова: ASSR • ABR • тугоухость • глухота • пороги • слух • дети

KORELACJA PROGÓW SŁYSZENIA SŁUCHOWYCH POTENCJAŁÓW STANU USTALONEGO Z PROGAMI SŁYSZENIA SŁUCHOWYCH POTENCJAŁÓW PNIA MÓZGU U DZIECI

Streszczenie

Wstęp: Ocena słuchu u noworodków lub starszych dzieci / nastolatków specjalnej troski jest bardzo trudna ponieważ wykonanie audiometrii tonalnej nie jest możliwe ze względu na brak współpracy, a pomiar słuchowych potencjałów pnia mózgu (ABR) wywołanych przez trzaski nie jest specyficzny częstotliwościowo.

Cel: Ocena wartości potencjałów słuchowych stanu ustalonego (ASSR) u noworodków lub u dzieci i młodzieży niewspółpracującej oraz korelacja uzyskanych progów słyszenia z progami uzyskanymi na podstawie ABR.

Materiał i metody: Za pomocą ABR i ASSR dokonano oceny progów słyszenia u 119 dzieci zbyt młodych, aby wykonać audiometrię behawioralną, oraz starszych dzieci lub nastolatków specjalnej troski (którzy nie byli w stanie lub nie chcieli poddać się badaniu audiometrii tonalnej). Zakres wieku wynosił od 1 miesiąca do 18 lat, średnia wieku 2,7 roku, a mediana 2,3 roku; zdecydowana większość (106 czyli 89%) była młodsza niż 5 lat.

Wyniki: Stwierdzono, że ASSR jest wartościową i obiektywną metodą oceny słuchu, ponieważ stwierdzono silną korelację progów uzyskanych w wyniku wykonania testów ABR i ASSR dla wszystkich częstotliwości (500, 1000, 2000 i 4000 Hz) ze współczynnikami korelacji rang Spearmana wynoszącymi od 0,83 do 0,87 i wysoką istotność statystyczną (p <0,0001).

Wnioski: Wyniki niniejszego badania potwierdzają wiarygodność ASSR oraz wskazują na silną korelację między progami ASSR i ABR nawet przy częstotliwości 500 Hz.

Słowa kluczowe: ASSR • ABR • niedosłuch • głuchota • progi • słuch • dzieci

Introduction

The auditory steady-state response (ASSR) can be thought of as an electrophysiologic response to rapid auditory stimuli. The goal of ASSR is to create an estimated audiogram from which questions regarding hearing, hearing loss, and aural rehabilitation can be answered (1). ASSR allows the hearing care professional to create statistically valid audiograms for those unable or unwilling to participate in traditional behavioral tests.

It is well known that it is very difficult to perform a pure tone audiogram in children younger than 4 years of age and sometimes the examination is so subjective and misleading in these children (or in older children with or without special needs) that management may become problematic

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or even harmful. ASSR relies on statistical measures to determine if and when a threshold is present. Therefore, ASSRs are important for young children and adults who cannot or will not cooperate with the audiologist for a pure tone audiogram.

In some respects ASSR is similar to the auditory brainstem response (ABR). For example, ASSR and ABR both record bioelectric activity from electrodes arranged in similar arrays. They are both auditory evoked potentials, and they both use acoustic stimuli delivered (preferably) through inserts.

ASSR and ABR also have important differences. Rather than depending on amplitude and latency, ASSR uses amplitudes and phases in the spectral (frequency) domain. ASSR depends on peak detection across a spectrum, rather than peak detection across an amplitude-versus-time waveform. ASSR is evoked using repeated sound stimuli presented at a high repetition rate, whereas ABR is evoked using brief sounds presented at a relatively low repetition rate (2).

Although both ABR and ASSR have been extensively used in pediatric audiology, recently there has been increasing interest in comparing the two methods (3-5). Aimoni et al. (2018) reported that ASSR can be considered an effective procedure and a reliable test, particularly when predicting hearing threshold in very young children at lower frequencies (including 0.5 kHz) (6). ASSR's superiority over click-ABR is that the latter are not frequency-specific. Kandogan and Dalgic (2013) also reported that both ABR and ASSR techniques may be used to provide an estimate of hearing sensitivity in children, but ASSR is a more valuable test than ABR, especially for cochlear implant candidates (7).

The aim of the present study is to correlate the hearing thresholds derived from ABR to the thresholds derived from ASSR.

Subjects and Methods

The subjects of the present study were 119 children (48 girls and 71 boys) too young to perform behavioral audiometry which included older children or teenagers with special needs (who were unable or unwilling to perform a pure tone audiogram). The age range was 1 month to 18 years old with a mean age of 2.7 years and a median of 2.3 years. From the 119 subjects, 106 (89%) were younger than 5 years and 13 (11%) older than 5 years, indicating that the vast majority were young children.

All subjects were assessed in the Clinic of Pediatric Hearing Loss, which operates in the context of the Attikon University Hospital Neonatal Hearing Screening and Cochlear Implant Program, a program that has a 14% initial failure rate. The children were given a full ENT examination, and underwent tympanometry, transient-evoked otoacoustic emissions (TEOAEs), and automated ABR (a-ABR). Detailed past medical and family histories were also taken.

Children failing the assessment were subsequently subjected to TEOAEs, click-chirp evoked ABR, and ASSR testing (90 Hz sleeping child default mode) under sedation with 4% chloral hydrate (1 mg/kg, max dose 1.5 mg/kg), or hydroxyzine hydrochloride 10 mg/5 ml (for older children and under the guidance of a pediatrician).

To record the ASSR, the Eclipse Platform from Interacoustics was used (the Eclipse modules work with Otoaccess). Data acquisition for ASSR recording took place from surface electrodes mounted at specific recording points on the patient. The electrode signals were amplified in an external preamplifier connected to the mounted surface electrodes. The amplified ASSR recordings were converted into digital signals within the Eclipse. Using a PC, the digital ASSR recordings were processed to determine whether or not a response was present.

Preparation prior to the test involved:

- Preparation of the skin. The electrode sites were prepared and cleaned with a paste to obtain acceptably low skin impedance. The paste was then cleaned off with alcohol.
- Placement of the electrodes. Electrodes were placed at each mastoid (blue lead on left, red on right), one at the vertex (white lead), and the ground connection (black) low on the forehead.
- Impedance check. Acceptable skin impedance was 3–5 kΩ.
- Insertion of the insert earphones. Earphones with foam tips were used.

The test protocol involved use of the neonate protocol (binaural threshold) with a stimulus rate of 90 Hz (EPA 4 preamplifier with two channels with frequency response up to 8000 Hz). Each channel used levels of 0–100 dB nHL in 5 dB steps at frequencies of 500, 1000, 2000, and 4000 Hz. An analysis time of 6 min was used at each point.

Statistical analysis was performed using Statgraphics and the variables were considered normal when the standardized kurtosis coefficient test was $<|2|$ and the standardized skewness coefficient test $<|2|$. Since the variables did not meet the criteria for a normal distribution, a nonparametric analysis involving Spearman rank correlation coefficients was used. Statistical significance was set at a level of $p < 0.05$.

The hearing thresholds derived from ABR were correlated with those from ASSR (the estimated audiogram). For statistical analysis, when no response was seen using a stimulus of 100 dB then the threshold was considered to be 110 dB. On the same basis, if a threshold of 20 dB or less was not detected, and the procedure was terminated due to time restraints, this was considered as threshold.

The study was approved by the ethical committee of Athens University (AU 8207).

Results

The results showed there was a strong correlation between ABR-derived and ASSR-derived thresholds at all

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Table 1. Spearman rank correlation coefficients between ABR-derived and ASSR-derived hearing thresholds

	ASSR-500	ASSR-1000	ASSR-2000	ASSR-4000
ABR-RIGHT	0.83	0.87	0.86	0.86
ABR-LEFT	0.84	0.85	0.86	0.87

All correlations were highly statistically significant with $p < 0.0001$

frequencies (500, 1000, 2000, and 4000 Hz) as shown in Table 1. There was a slightly higher correlation for frequencies above 500 Hz.

Discussion

Inclusion of the ASSR into test batteries for objective audiometry allows clinical comparisons to be made with the most widely used procedure, the ABR.

Swanepoel and Ebrahim (8) assessed 48 children and compared the ASSR and ABR thresholds for various types and degrees of hearing loss. The correlations between the ABR and individual ASSR frequencies ranged from 0.82 to 0.86 and this is in agreement with the correlations found in the present paper. However, Celic et al. (4) found only a moderate positive correlation between the results of ABR and ASSR responses at 1000 Hz and the mean values of 1000–4000 Hz and 2000–4000 Hz in the hearing-impaired group ($r = 0.419$, $p = 0.008$; $r = 0.370$, $p = 0.02$; and $r = 0.408$, $p = 0.01$, respectively). A stronger correlation was found between 4000 Hz ASSR thresholds and ABR thresholds in the hearing-impaired subjects ($r = 0.506$, $p = 0.001$). The authors concluded that ASSR may not be a beneficial and/or reliable screening test for hearing impairment in infants. However, it might detect affected frequencies in patients with hearing loss and could confirm the results of other tests. Thus, their final conclusion was that ASSR may be considered to be a complementary test rather than an alternative to ABR. In contrast, Vander Werff et al. (9) investigated the degree to which ASSR thresholds correlated with ABR thresholds in a group of sedated children with a range of hearing losses. Thirty-two children from the University of Iowa Hospitals and Clinics, ranging in age from 2 months to 3 years and presenting with a range of ABR thresholds, participated. Strong correlations were found between the 2000-Hz ASSR thresholds and click-ABR thresholds ($r = 0.96$), the average of the 2000- and 4000-Hz ASSR thresholds and click-ABR thresholds ($r = 0.97$), and the 500-Hz ASSR and 500-Hz tone-burst ABR thresholds ($r = 0.86$). Additionally, it was possible to measure ASSR thresholds for several children with hearing loss that were sufficiently great to result in no ABR at the limits of the equipment. The results of the above-mentioned studies indicate that the ASSR may provide a reasonable alternative to the ABR for estimating audiometric thresholds in very young children.

Mourtzouchos et al. (2018) found strong, statistically significant correlations between the average of the 1000, 2000, and 4000 Hz chirp-ASSR thresholds and click-ABR thresholds ($rs = 0.826$, $p < 0.001$), and similarly with the average of the 2000 and 4000 Hz chirp ASSR and click-ABR thresholds ($rs = 0.824$, $p < 0.001$). Additionally, they found measurements for some children with hearing loss in the severe-to-profound range during the ASSR test, but who had no ABR at the upper limits of the equipment. Click-ABR and chirp-ASSR thresholds averaged at 2000 and 4000 Hz were within 20 dB in 90% of the ears tested (10).

The notion that ASSRs may be a more accurate predictor of behavioral thresholds than ABRs in certain individuals with steeply sloping hearing losses has also been supported by Johnson and Brown (11) and Cone-Wesson et al. (12) who have suggested that ASSR thresholds can be used to predict the configuration of pure tone audiometry. Moreover, according to other studies, the potential difference between pure-tone and ASSR thresholds in the hearing impaired population does not usually exceed 10 dB, depending on the frequency (13,14).

The results of the present study further support the reliability of ASSR and suggest that the strong correlation between ASSR and ABR thresholds is maintained even in the region of 500 Hz.

Conflicts of interest:

None declared. The authors have no financial interest and have not received any financial support for this article.

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