

A resposta auditiva de estado estável na avaliação auditiva: aplicação clínica*****

Auditory steady-state response in the auditory evaluation: clinical application

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Abstract

Background: the auditory steady state response (ASSR) is an electrophysiological procedure that evaluates, at the same time, the hearing thresholds of both ears at various frequencies. This procedure reduces the time of testing and enables the stimulation of levels close to 125dB HL, characterizing residual hearing. **Aim:** to verify the applicability of the ASSR to determine the hearing thresholds in different levels of sensorineural hearing loss. **Method:** 48 individuals aged 7-30 years, with different levels of hearing loss were assessed. The Pure tone Audiometry (PTA) and the ASSR were carried out in following carrier frequencies 0.5; 1; 2 and 4k Hz. The carrier frequencies in the ASSR were modulated in amplitude and frequency, with multiple dicotic stimulation for mild and moderate hearing loss. Simple stimulation was used to test the other hearing deficit levels. **Results:** there was a significant association ($p < 0.01$) between the thresholds obtained in the PTA and in the ASSR for all of the tested frequencies, especially for the severe levels. However, for some patients, the hearing loss level was overestimated in the ASSR. **Conclusion:** the ASSR can be used to estimate the PTA threshold; nevertheless, it should not be analyzed in an isolated way, but seen as a complementary procedure to the behavioral auditory assessment.

Key Words: Auditory Evoked Potential; Steady-State; Audiometry; Sensorineural Hearing Loss.

Resumo

Tema: a resposta auditiva de estado estável (RAEE) é um procedimento eletrofisiológico que permite avaliar ao mesmo tempo os limiares auditivos de várias frequências em ambas às orelhas, reduzindo assim o tempo de teste, e permite estimular até níveis próximos a 125dB HL, caracterizando assim a audição residual. **Objetivo:** verificar a aplicabilidade da RAEE para determinar os limiares auditivos nos diferentes graus de perda auditiva neurossensorial coclear. **Método:** foram avaliados 48 indivíduos com idade entre sete e trinta anos e diferentes graus de perdas auditivas. A Audiometria Tonal Liminar (ATL) e a RAEE foram avaliadas nas seguintes frequências portadoras, 0,5; 1; 2 e 4k Hz. As frequências portadoras na RAEE foram moduladas em amplitude e frequência, com estimulação múltipla e dicótica nas perdas auditivas de grau leve e moderado. Estimulação simples foi utilizada nos outros graus de perdas auditivas. **Resultados:** houve associação significativa ($p < 0,01$) entre os limiares obtidos na ATL e RAEE para todas as frequências testadas, principalmente para perdas auditivas de grau profundo. Contudo em alguns pacientes o grau da perda auditiva pode ser super-estimado. **Conclusão:** a RAEE pode ser utilizada para prever os limiares auditivos da ATL, porém não deve ser analisada de forma isolada, mas de forma complementar a avaliação audiológica comportamental.

Palavras-Chave: Potenciais Evocados Auditivos; Estado Estável; Audiometria; Perda Auditiva Neurossensorial.

Introduction

The Auditory Steady-State Response (ASSR) is an electrophysiological exam that has been used in large services as an auxiliary procedure on the diagnosis of infantile hearing losses. One of its most important advantages is the possibility to assess several frequencies simultaneously while presenting them to both ears at the same time (1,2,3,4) thus decreasing the testing time if compared to the same assessment using the Auditory Brainstem Response (ABR) with tone burst stimulus (5,6,7). The use of test stimulus that allows the assessment even of frequencies near 125dBHL contributes to the measurement of auditory residuals in cases of severe and profound hearing losses with no responses on ABR assessments (5,8). Furthermore, the decision about response presence or absence is defined with the use of statistical techniques (9,10).

In cases of sensorial hearing losses the thresholds determined by the ASSR has shown strong correlations with behavioral thresholds determined by the Visual Reinforcement Audiometry (VRA) and/or conditioned audiometry (6,11,12,13,14,15,16), as well as by the pure tone audiometry (PTA) (17,18,19,20,21). In what refers to the degree of sensorial hearing loss the studies show weaker correlations with the less severe losses (22,7,23,24). However, most of the studies focused mostly on hearing losses of severe and profound degrees showing the necessity of research about the relations between PTA and ASSR also in less severe hearing losses. The aim of the present study was to verify the association between tonal thresholds and the ones obtained in the ASSR in individuals with varying degrees of sensorial hearing losses.

Method

The study was conducted on the Hearing, Speech and Language Clinic of Bauru Dental School and on the Center of Audiology Research of the Hospital for Rehabilitation of Craniofacial Anomalies, both of the University of Sao Paulo (USP) and was approved by the institution's ethic committee (process number 100/2005).

Subjects were 48 individuals with diagnosis of sensorial hearing losses, 25 of the male gender and 23 of the female gender with mean age 15:9 (\pm 6:5), the younger with eight and the older with 30 years. The lower age was defined in order to obtain reliable hearing thresholds of PTA.

The ASSR was realized in both ears with the exception of the subjects with which it was done only on the right ear because the child woke-up and didn't return to continue the test.

Assessment procedure

All subjects were examined by a otorhinolaringologist in order to guarantee adequate conditions for auditory assessment.

The pure tone audiometry was realized in an acoustic cabin with a Madsen audiometer of Midimate 622 model using TDH-39 over-aural phones. The frequencies of 0.5, 1, 2 and 4 kHz were assessed by bone conduction in both ears in order to confirm the hearing thresholds and the audiogram's configuration on the testing day. Maximum intensity tested were 60dBHL by bone conduction and 115, 120, 115 and 115 dBHL by air conduction to the frequencies of 0.5, 1, 2, and 4kHz respectively. A tympanometry was also conducted to guarantee the middle ear functionality on the moment of assessment.

Auditory Steady-State Response (ASSR)

The ASSR thresholds were assessed on the same day of the conventional audiological evaluation using the MASTER (Multiple Auditory Steady-State Response) system on its 2.04.i00 version by Bio-logic Systems Corp.

Stimulus

Two parameters of stimulus presentation were used due to the different degrees of hearing loss and to the sound presentation patterns available by the equipment.

First parameter (mild, and moderate hearing losses)

The frequencies of 0.5; 1; 2 and kHz were assessed simultaneously and on both ears with the presentation of eight stimuli (four on each ear) 100% modulated for amplitude and 20% for frequency. The modulation frequencies were 84.375; 89.062; 93.750 Hz for the right ear and 82.031; 86.719; 91.406 and 96.094 Hz to the left ear. The stimuli were presented through 3A insertion phones starting with 80dBHL of intensity to individuals with moderate hearing loss and 50dBHL with mild hearing loss with decreasing steps of 10dB until no response was observed and increasing with 5dB steps to determine the electrophysiological threshold.

Second parameter (severe and profound hearing losses)

The frequencies of 0.5; 1; 2 and 4 kHz were assessed with simple and dichotic stimulation because the equipment doesn't allow multiple stimulation of the same ear on intensities above 80dBHL. The assessment of the ASSR threshold started with the 0.5 kHz frequency, followed by 4 kHz, 1 kHz and 2 kHz, respectively. The frequencies were 1005 modulated for amplitude and 20% for frequency with 69.141Hz as the modulation frequency to the right ear and 66.797Hz to the left ear on all the frequencies assessed. The stimuli were presented through 3A insertion phones starting with 100dBHL of intensity to individuals with severe hearing loss and with the maximum intensity provided by the equipment with individuals with profound hearing loss. The intensities were 117 dBHL to the 0.5 kHz frequency, 121 dBHL to the 1 kHz frequency, 119 dBHL to the 2 kHz frequency and 118 kHz to the 4 kHz frequency. The threshold was determined by decreasing steps of 10dB until no response was observed and increasing with 5dB steps to determine the electrophysiological threshold.

ASSR record

To the ASSR record the individual comfortably laid in natural sleep or relaxed on a gurney placed inside a cabin with acoustic and electrical isolation within an acoustic treated room. Disposable electrodes were positioned in Fz (active electrode), Oz (reference) and Fpz (ground) with impedances kept below 5 Kohm and differences among impedances lesser than 2 Kohm. The electroencephalogram was obtained using a 50000 gain, low-pass filter of 1Hz to 300 Hz, 6 dB/octave and analogical-digital (AD) conversion rhythm of 1kHz.

Each screening lasted 16 seconds and had 16 periods of 1 second each. A period was rejected if the amplitude exceeded $\pm 40 \mu V$. The number of screening was determined based on the response onset or on the intensity tested. On intensities equal

or above 90 dBHL it varied from 10 to 12. On intensities equal or below 80 dBHL it varied from 18 to 45. The intensity was decreased in 10 dB when the response statistically significant and didn't change in 12 consecutive screenings (26).

ASSR analysis

The screenings were automatically analyzed using the frequency range resulting from the Fast Fourier Transform (FFT). It consisted on the verification of the ASSR amplitude on a specific frequency of modulation compared to the adjacent frequencies (60 frequency bins below and 60 frequency bins above the response) and analyzed through a F test with confidence interval of 95% (27). A response was considered present with p value $p < 0.05$.

Data analysis

The data analysis used the Pearson (r) correlation coefficient to compare the thresholds obtained by PTA and ASSR and the study of the agreement rate of the degree of the hearing loss and its respective agreement rate (Kappa).

Results

On the individual analysis of the results it was observed that some individuals with profound sensorial hearing losses presented responses on the PTA and didn't on the ASSR or presented no response on either procedure. The Pearson correlation coefficients that compared PTA and ASSR thresholds on 0.5, 1, 2 and 4 kHz were respectively 0.88; 0.93; 0.93 and 0.88 to the right ear and 0.82; 0.87; 0.90 and 0.90 to the left ear. These coefficients were statistically significant ($p < 0.01$).

Tables 1 and 2 present the hearing level classification to PTA and ASSR determined by the average of the thresholds on the frequencies of 0.5, 1, 2 and 4 kHz according to the WHO (25), 1997. Table 3 shows the Kappa agreement coefficient observed on both procedures.

TABLE 1. Distribution of the population according to the classification of the hearing level determined to the right ear defined by the average of the thresholds on 0.5 and 4 kHz frequencies (WHO, 1997) of the Pure Tone Audiometry and of the Auditory Steady-State Response.

Hearing Level Classification – Right Ear												
*ASSR												
**PTA	# Normal		Mild		Moderate		Severe		Profound		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Normal	1	2	2	2	1	4	-	-	-	-	4	8
Mild	-	-	1	2	5	10	1	2	-	-	7	15
Moderate	-	-	-	-	2	4	5	10	4	8	11	23
Severe	-	-	-	-	-	-	2	4	6	13	8	17
Profound	-	-	-	-	-	-	-	-	18	38	18	38
Total	1	2	3	6	8	17	8	17	28	58	48	100

Legend: *ASSR – Auditory Steady-State Response; **PTA – Pure Tone Audiometry, # Individual with descendant audiometric curve configuration on the right ear

TABLE 2. Distribution of the population according to the classification of the hearing level determined to the left ear defined by the average of the thresholds on 0.5 and 4 kHz frequencies (WHO, 1997) of the Pure Tone Audiometry and of the Auditory Steady-State Response.

Hearing Level Classification – Left Ear												
*ASSR												
**PTA	# Normal		Mild		Moderate		Severe		Profound		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Normal	1	2	-	-	-	-	1	2	-	-	2	4
Mild	-	-	1	2	5	11	1	2	-	-	7	15
Moderate	-	-	1	2	3	7	4	9	-	-	8	17
Severe	-	-	-	-	-	-	4	9	6	13	10	22
Profound	-	-	-	-	-	-	-	-	19	41	19	41
Total	1	2	2	4	8	17	10	22	25	54	46	100

Legend: *ASSR – Auditory Steady-State Response; **PTA – Pure Tone Audiometry, # Individual with descendant audiometric curve configuration on the left ear

TABLE 3. Values of Kappa agreement coefficient between the degree of the hearing loss on the Pure Tone Audiometry and the Auditory Steady-State Response on both ears.

EAR	Observed agreement (%)	Kappa	Confidence interval (95%)	
			Low Limit	High Limit
Right	50	0.74	0.58	0.84
Left	61	0.77	0.58	0.87

Discussion

The implementation of the newborn hearing screening on programs of hearing health the professionals that work on reference centers must be able to perform audiological diagnosis and treatment, if necessary, on newborns identified as being at risk for hearing loss.

Among the available procedures to the hearing assessment in children the ASSR is an electrophysiological procedure that has been widely researched in national and international centers due to the advantages it may provide to the hearing assessment in children, such as to provide information about the psychoacoustic thresholds of an age that do not have the necessary cognitive development to answer to the behavioral methods.

Other important aspect is that the cochlear implant is being indicated to increasing earlier ages (less than 1 year) and the ASSR is presented as a promising procedure to determine the tonal threshold of this population. The audiometry by ASSR fills a gap of the audiological evaluation because the ABR has a limitation of the maximum testing intensity (normally 90 dBHL), thus not measuring residual hearing (14). Finally, the tonal audiometry by ASSR can be realized in less time then the ABR audiometry (5,6).

However, since it is a relatively new procedure studies about the relation between behavioral thresholds defined by the PTA and the ASSR are still needed.

It can be observed that there was a significant association ($p < 0.01$) of the hearing thresholds determined by the PTA and by the ASSR and that the correlation coefficients (r) have shown strong correlation between the procedures, agreeing with other studies (17, 18, 19, 20).

Several studies reported fewer correlations of PTA and ASSR thresholds on the 0.5 kHz frequency (17, 7, 23) as well as on the 4kHz frequency (21). A possible explanation could be the type of stimulus modulation because instead of amplitude modulation or amplitude and frequency modulation (7, 21) this study used the exponential amplitude modulation associated to the modulation of frequency. The exponential modulation generates larger amplitudes to all frequencies, allowing better observation of the 0.5 and 4 kHz frequencies (28).

With the aim to verify if the threshold determined by PTA and ASSR classified hearing losses on a similar way, the 1997 WHO classification (25) which considers the average of 0.5 to 4 kHz frequencies was used (Tables 1 and 2).

The Kappa agreement coefficient to the hearing loss degree was 0.74 to the right ear and 0.77 to the left ear with the lower limit of the confidence interval near 0.60 what may suggest that on some moments the agreement was moderate (Table 3). According to Tables 1 and 2 it was possible to observe that in some individuals the ASSR pointed out to a higher level of hearing loss than the PTA specially in those with less severe hearing losses.

Analyzing specifically the profound hearing loss there was a stronger agreement of the procedures. The findings agree with the ones described on the literature (22,7,23). However, it was observed that even with few occurrences, the profound hearing loss defined by the ASSR referred to severe and moderate hearing losses defined by the PTA (Tables 1 and 2).

Therefore, the possibility that the ASSR overestimate the degree of the hearing loss in some patients should be considered, as it is already the case with the evoked brainstem auditory potentials. This difference is to be expected once procedures

that evaluate different responses are being compared. That is the pure tone audiometry evaluates the auditory functions and on the contrary the electrophysiological procedures are directly dependent on the structure of the hearing system that generates the response.

This way, the thresholds determined by the ASSR as other procedures used in the audiological evaluation of children should not be used as the single information while defining the adjustments on the individual hearing aids. It is also important to note that the maximum and best use of the hearing aid device is essential to the cochlear implant indication, electronic device used in severe and profound hearing losses which do not benefit from amplification.

It is important to point out that despite this study compare ASSR with PTA and not with VRA (Visual Reinforced Audiometry) and/or conditioned audiometry that are used with infant and preschoolers the finding were similar (11,12,13,16,14,15,16) in what refers to the strong correlations of VRA and/or conditioned audiometry and ASSR to sensorial hearing losses, with larger differences between thresholds in mild hearing losses (11,12) and smaller on the more severe ones (12). However, no study with an analysis similar to the one presented in this research was found on the literature.

The results obtained have shown that the ASSR is a valid procedure to predict the hearing threshold, especially in the cases of more severe hearing losses. However future studies should focus on the infantile population more specifically in newborns and babies, ages in which the procedure has larger clinical applicability once it is not possible to obtain precise responses on behavioral tests.

Conclusion

This study with 48 individuals with sensorial hearing loss allowed the conclusion that there is an association of the ASSR and the PTA thresholds, with larger agreement on more severe hearing losses.

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