

# Comparative Study Between Auditory Steady-State Responses, Auditory Brain-Stem Responses, and Liminar Tonal Audiometry

Asunción Martínez Fernández,<sup>a</sup> Miguel Ángel Alañón Fernández,<sup>a</sup> Luis Félix Ayala Martínez,<sup>a</sup> Ana Belén Álvarez Álvarez,<sup>b</sup> María Teresa Miranda León,<sup>c</sup> and Manuel Sainz Quevedo<sup>d</sup>

<sup>a</sup>Servicio de Otorrinolaringología, Hospital Santa Bárbara, Puertollano, Ciudad Real, Spain

<sup>b</sup>Servicio de Otorrinolaringología, Hospital General, Ciudad Real, Spain

<sup>c</sup>Departamento de Estadística, Facultad de Medicina, Universidad de Granada, Granada, Spain

<sup>d</sup>Servicio de Otorrinolaringología, Hospital Clínico Universitario San Cecilio, Granada, Spain

**Objectives:** Auditory steady-state responses (ASSR) using frequencies of modulation between 70-110 Hz are a new auditive exploration technique. The aim of the study was to evaluate the contribution of the ASSR to diagnostic of the audition.

**Material and method:** Different aportations of auditory steady-states responses (ASSR) and auditory brain-stem responses (ABR) to diagnostic of thresholds of audition were studied. Differences between these thresholds and thresholds obtained by liminar tonal audiometry (LTA) were studied too. Correlations between thresholds obtained by ASSR and LTA were studied.

**Results:** ASSR detected rest of audidtion that transients ABR did not detect. Differences about -13.750 dB HL (-5.209 to -22.291) and -13.250 dB HL (-7.337 to -19.163) were found between registered values for carriers of 500 and 1000 Hz and the thresholds by LTA for these carriers. Differences about 1.625 dB HL (-6.967 to 10.217) and -2.875 dB HL (-7.446 to 1.696) were found between estimations for the carries of 500 and 1000 Hz and thresholds by TLA. Stadistically very signifnificant ( $P=.01$ ) coefficients of correlation were found between registered and estimated thresholds by ASSR for carrier of 500 and 1000 Hz and threshold by TLA for these frecuencias.

**Conclusions:** Auditory steady-state response (ASSR) using frequencies of modulation between 70-110 Hz are a new auditive technique of exploration. This stimulus is more frequency-specific than clicks for auditory brain-stem

**Estudio comparativo entre potenciales evocados auditivos de estado estable, potenciales evocados auditivos de tronco cerebral y audiometría tonal liminar**

**Objetivos:** Los potenciales evocados auditivos de estado estable (PEAee) con frecuencias de modulación de 70-110 Hz son una nueva técnica para explorar la audición. Nos proponemos valorar su aportación al diagnóstico audiológico.

**Material y método:** Se estudió las diferentes aportaciones al diagnóstico del umbral auditivo de los PEAee y los potenciales evocados auditivos de tronco cerebral (PEATC) en respuesta al clic. Además se estudió las diferencias entre estos umbrales y los de la audiometría tonal liminar (ATL). Se analiza los coeficientes de correlación entre los umbrales obtenidos en PEAee y los de la ATL.

**Resultados:** Los PEAee permitieron detectar restos de audición que no eran detectados mediante PEATC transitorios. Se encontraron diferencias de -13.750 dB HL (-22.291 a -5.209) y de -13.250 dB HL (-19.163 a -7.337) entre los valores registrados mediante PEAee para las frecuencias de 500 y 1000 Hz y los umbrales de la ATL para esas mismas frecuencias. Se encontraron diferencias de 1.625 dB HL (-6.967 a 10.217) y de -2.875 dB HL (-7.446 a 1.696) entre los valores estimados en los PEAee y los umbrales de la ATL para las frecuencias de 500 y 1000 Hz. Los coeficientes de correlación fueron estadísticamente muy significativos ( $P=.01$ ) entre los umbrales registrados y los estimados en los PEAee para las portadoras de 500 y 1000 Hz y los de la ATL para las mismas frecuencias.

**Conclusiones:** Los PEAee con frecuencias de modulación entre 70 y 110 Hz constituyen una nueva técnica de exploración de la audición, que es más específica en frecuencia que los PEATC en respuesta al clic. La respuesta obtenida no se modificará por el estado de conciencia y

Correspondence: Dr. A. Martínez Fernández.  
Santa Bárbara, 4, Portal D, 2.º D. 13003 Ciudad Real. España.  
E-mail: miguelaaf@msn.com

Received October 19, 2006.

Accepted for publication May 25, 2007.

responses (ABR) to clicks. Response is not modified by steady of consciousness. The technique is doubly objective. Thresholds obtained by ASSR permits to estimation of the audition threshold.

**Key words:** Auditory steady-state responses. Continuous auditory evoked potential. Auditory brain-stem responses. Modulated tone.

además es una técnica doblemente objetiva. Los umbrales obtenidos en los PEAAe permiten realizar una estimación del umbral de audición.

**Palabras clave:** Potenciales evocados auditivos de estado estable. Potenciales evocados auditivos continuos. Potenciales evocados auditivos de tronco cerebral. Tono modulado.

## INTRODUCTION

The auditory system possesses a consistent specific function for making sound stimuli perceptible. To do so, the external ear and the middle ear are responsible for transmitting sound waves to the inner ear; the inner ear is responsible for mechanical to electrical transduction and lastly the nerve paths carry the impulse generated to the brainstem.

In signal analysis, the peripheral auditory system acts as a series of filters in a chain:

1. Mechanical. Passive: basilar membrane, active: external ciliary cells.
2. Neural: efferent olivocochlear system.

Thanks to these a 3-fold discrimination is possible: a) frequency discrimination between 20 and 20 000 Hz; b) intensity discrimination of up to 130 dB; and c) temporal discrimination of 1 ms.

A series of nuclei is found in the central auditory system (cochlear nucleus, superior olivary complex, lateral lemniscus nucleus, inferior colliculus, and middle geniculate body) that not only constitute relays to the cortex, but act as high-level integration centres contributing to binaural discrimination, frequency discrimination and signal modulation discrimination, in both frequency, and amplitude modulation. At these centres, there is also a multisensorial integration receiving input from other systems, at the same time as it is closely related to the efferent olivocochlear system. With all these elements, human hearing performs its specific function, and it is up to us otorhinolaryngologists to know and explore this system because the early and appropriate diagnosis and treatment of hearing loss has become essential in the wake of current advances in audiology. The use of auditory brainstem responses (ABR) to clicks has the disadvantage that the greatest energy of the click is concentrated in the range of the highest frequencies and the test is not frequency-specific. As a result, exam methods are sought that are objective, independent of the patient's wakeful/sleeping state and specific from the frequency point of view. This search has given rise to the auditory steady-state response (ASSR),<sup>1,4</sup> a technique that can be found by various names in the scientific literature: continuous auditory responses,<sup>2</sup> steady-state evoked potential (SSEP),<sup>3</sup> or amplitude-modulation following response (AMFR).<sup>5</sup>

ASSRs are defined as quasi-sinusoidal periodic responses whose amplitude and phase characteristics remain constant over time.

This type of response is generated when a stimulus is presented at a frequency such that it overlaps the one originated by the next stimulus.

Its origin depends on the modulation frequencies used:

- Modulation frequencies between 4 and 8 Hz will give rise to responses that overlap approximately every 100 ms; thus, they originate by the overlapping of cortical-type responses
- Modulation frequencies between 20 and 70 Hz will give rise to responses that overlap approximately every 30 ms or, in other words, by overlapping of the medium latency responses, and the 40 Hz test is a classic technique
- Modulation frequencies between 70 and 110 Hz will give rise to responses that overlap approximately every 10 ms or, similarly, by overlapping of the brain stem responses<sup>6</sup>

The type of stimulus used will be continuous modulated tones, although the modulation can be applied only to the amplitude, either linearly (AM) or exponentially (AM<sup>2</sup>), or only to the frequency modulation (FM), or else as a modulation of both at the same time, mixed modulation (MM). Another stimulation modality, known as multifrequency, is through a mixture of modulated tones. The stimulus can be performed monaurally or binaurally, using either the air or the bone pathways.

With this type of stimulus, a periodic semisinusoidal response is obtained; defined by parameters of amplitude and frequency, this type of response allows the application of an FFT (fast Fourier transform) to convert them by their amplitude and phase parameters, and the response is represented as a peak on the spectrum at the modulation frequency. Thanks to this, it is possible to use a series of statistics calculated in the frequency domain to determine whether or not there is a response. The statistical analysis of the signal is performed in real time. Thanks to the use of these statistics, the technique will be doubly objective, because it does not require analysis on the part of the examiner nor the collaboration of the study subject. The statistics used in response detection vary depending on the equipment used: a) F hidden periodicity test and phase weighted test/CP, and CMS (Picton et al<sup>7</sup>), and b) T2H, F test/T2C, and CMS (Pérez-Ábalo et al<sup>1</sup>).

The purpose of our study is to evaluate the contribution of ASSR in audiological diagnosis, to which end we proceeded to compare their contribution with respect to ABR and tonal liminar audiometry (LTA). We have studied the types of steady-state auditory responses that exist, their origin and anatomic-physiological bases as well as the types of stimulation that can be used and the corresponding response obtained and the various statistics used.

## MATERIAL AND METHOD

A total of 200 ears were studied (100 right and 100 left), belonging to 120 children aged between 5 months and 4 years, and in 80 adults between 18 and 53 years of age. Forty ears corresponded to children with normal hearing, another 40 to normal hearing adults, 80 to children with sensorineural hypoacusia, (90% profound, 15% moderate, and 5% mild), and another 40 to adults with sensorineural hypoacusia (50% profound, 45% moderate, 5% mild).

The LTA was performed in a conventional manner on the subjects whose ages allowed it, for which a correctly calibrated Interacoustic® audiometer was used.

For ABR and ASSR recording, Gradson-Stadler GSI Audera® auditory response equipment was used. In the case of the adult patients, it was performed without medication, with the patient relaxed or sleeping. Children under 9 months were sedated with nembutal and those older than nine months with variargil, adjusting the dosage by age, and in 30 cases the recording was performed under general anaesthesia. The duration of the test was 1 hour on average from the placement of the electrodes.

For the ABR recording, click-type stimuli were used, with an 11.1 Hz stimulation rate, with 4 presented ipsilaterally by air.

For the ASSR recording, the technique devised by Rance et al<sup>8,9</sup> was used. Pure modulated tones were used as stimuli (AM 90% and FM 10%), with a stimulus range between 70 and 100 Hz; 47 Hz were assigned to the 500 Hz carrier frequency and 81 Hz to the 1000 Hz signal, and they were presented monaurally and by air.

## Statistical Study

Version 12.0 of the SPSS application (Statistical Package for Social Sciences) was used. For descriptive statistics, the average, standard deviation, standard error, maximums, and minimums were found. For inferential statistics, after applying the Shapiro-Wilk and Kolmogorov-Smirnov normality tests, the general linear model was used, and after performing the variance analysis (Bartlett sphericity test and Greenhouse-Geisser, and Huynh-Feldt corrections), the multiple comparison process was applied with the Bonferroni correction to control the general alpha error.

Lastly, the correlations study between estimated thresholds and those recorded by ASSR and LTA was performed applying Spearman's rho as they are non-parametric data.

## RESULTS

A total of 17 subjects were excluded from the sample as no response was obtained in the exams performed. In 6 cases, this was due to an absence of response in the ABR as well as in ASSR; in 10 cases for a lack of response with ABR, with a response in ASSR at carrier frequencies of 500 and 1000 Hz in 5 cases, for that of 1000 Hz in 4 cases and for that of 500 Hz in 1 case. Lastly, due to an absence of response in ASSR at the 500 Hz carrier frequency (Figure 1).

Therefore, comparing ASSR with click ABR, we could say that ASSR has allowed us to detect hearing remnants that would have gone unnoticed if we had only performed the examination using the classic click ABR test.

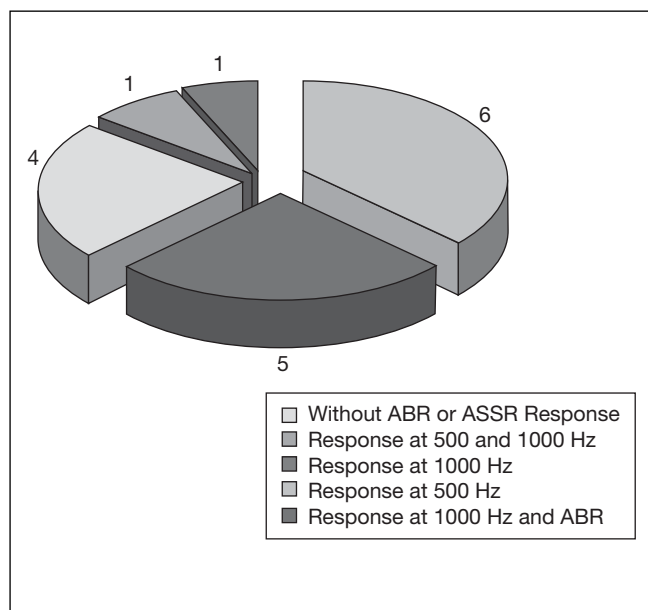
Given that click ASSR is not frequency-specific and is centred specifically in the audiogram area corresponding to frequencies between 2000 and 4000 Hz whereas ASSR, as well as being more specific in terms of frequency, allows us to explore the audiogram area corresponding to the frequencies of 500 and 1000 Hz, we are interested in knowing the differences between ASSR and LTA in the audiogram corresponding to these frequencies (500 and 1000 Hz).

The differences between LTA thresholds and those obtained through ASSR for the 500 and 1000 Hz carrier signals in absolute terms, as well as the confidence intervals for these differences, are shown in Table 1.

Applying Spearman's rho for the non-parametric analysis of the data, we obtained the correlation coefficients shown in Table 2.

## DISCUSSION

The results obtained in our study support the usefulness of ASSR as an objective and reliable diagnostic method.



**Figure 1.** Subjects excluded from the sample (n=17). ASSR indicates auditory steady-state response; ABR, auditory brain stem response.

In 10 cases, ASSR was capable of detecting a response that had not been detected with click ABR; in this sense it is necessary to point out the importance of this technique, since it allows us to explore residual hearing at low frequencies that it may be useful to exploit. This advantage is fundamentally due to 2 characteristics: *a)* the use of a stimulus capable of producing a more frequency-specific response than clicks, and *b)* it allows the use of greater stimulation intensities than clicks since the greatest stimulation intensity with clicks is around 100 dB HL whereas, using a pure modulated tone, we can push up the intensity to 105 dB HL for a 250 Hz frequency and up to 120 dB HL in the frequencies from 500 to 4000 Hz.

The noise results have complicated signal extraction and raised recording times, obliging us on 3 occasions to postpone the exam in awake subjects.

For authors such as Cohen et al,<sup>3</sup> the tests are more consistent when the electroencephalographic activity reflected is low. For Rickard et al,<sup>10</sup> the background noise of the electroencephalography complicates signal extraction and increases recording time. Savio et al<sup>11</sup> attribute these results to the masking effect produced by the level of background noise and with it the differences found by different authors; in this same sense, Lins et al<sup>12</sup> detect differences in their own recordings depending on the background noise.

As for the greater differences found when considering the 500 Hz carrier signal, various authors, as in the case of Dimitrijevic et al,<sup>13</sup> have attributed these to poor neural

synchronization at this frequency. In this sense, Rance et al,<sup>8,9</sup> when calculating regression curves, already spoke of a greater dispersion in data for the lowest frequencies, attributing this fact to poor neural synchronization at these levels. The papers published by Savio et al<sup>11</sup> and Lins et al<sup>12</sup> show that this effect is due not only to poor neural synchronization for these frequencies, but to a certain extent to the masking effect produced by the background noise, which has greater energy towards the lower frequencies.

When the data for healthy and hearing-loss subjects were compared we found fewer differences in the subjects affected by hypoacusia. Rance et al<sup>8,9</sup> already found that the dispersion in data on the regression curves was reduced when auditory loss was greater and increased when approaching normal thresholds. Dimitrijevic et al<sup>13</sup> found similar results when they observed that the amplitude of the responses was significantly greater in sensorineural hypoacusia than in normal subjects, and they attributed this to recruitment. It is thus logical to think that if the electrophysiological response presents a greater increase in amplitude with an increase in intensity when there is recruitment, the response will be more recognizable close to the threshold, as the studies by Savio et al,<sup>11</sup> Ponce de León,<sup>14</sup> and Lins et al<sup>12</sup> have shown. For these authors, too, by increasing the hearing loss up to a certain level (77-85 dB SPL), the masking produced by noise would cease to be effective.

In terms of the population group studied, the worst results were obtained in children. Obviously, the maturity of the system influences the production of lower amplitude

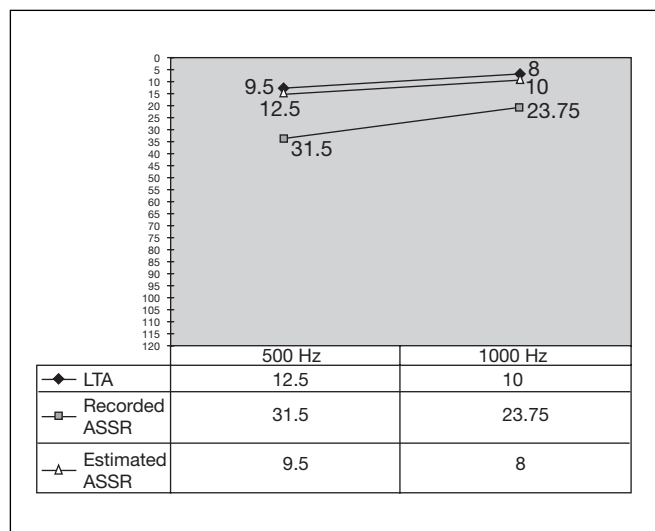
**Table 1.** Differences Expressed in dB HL Between the Thresholds Obtained Through Auditory Steady-State Response (ASSR) and Liminar Tonal Audiometry (LTA)

	ASSR Recorded at 500 Hz	ASSR Recorded at 1000 Hz	ASSR Estimated at 500 Hz	ASSR Estimated at 1000 Hz
All groups				
LTA 500 Hz	-13.750 (-22.291 to -5.209)		1.625 (-6.967 to 10.217)	
LTA 1000 Hz		-13.250 (-9.163 to -337)		-2.875 (-7.446 to 1.696)
Healthy subjects				
LTA 500 Hz	-18.750 (-30.829 to -6.671)		3.000 (-9.151 to 15.151)	
LTA 1000 Hz		-13.750 (-22.113 to -5.387)		2.000 (-4.465 to 8.465)
Hearing loss				
LTA 500 Hz	-8.750 (-20.829 to 3.329)		0.250 (-11.901 to 12.401)	
LTA 1000 Hz		-12.750 (-21.113 to -4.387)		-7.750 (-14.215 to -1.285)

**Table 2.** Correlation Coefficients\*

	ASSR Recorded at 500 Hz	ASSR Recorded at 1000 Hz	Estimated ASSR at 500 Hz	Estimated ASSR at 1000 Hz
Left ears				
LTA 500 Hz	0.826		0.847	
LTA 1000 Hz		0.975		0.975
Right ears				
LTA 500 Hz	0.885		0.910	
LTA 1000 Hz		0.938		0.953

\*LTA indicates liminar tonal audiometry; ASSR, auditory steady-state response.



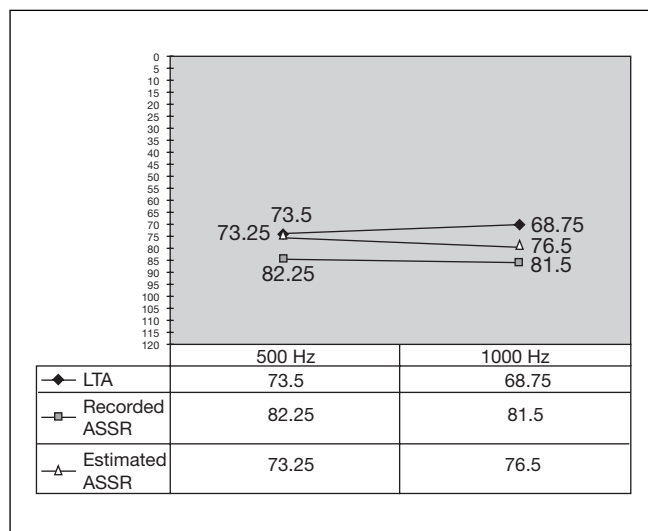
**Figure 2.** Differences in the group of healthy subjects (scale of dB HL for the carrier signals at 500 and 1000 Hz, respectively). LTA indicates liminar tonal audiometry; ASSR, auditory steady state response.

responses that depend on the maturity of the auditory system.<sup>10</sup> Our sample was also influenced in this sense by the fact that, for some children on whom the test was not performed during sleep deprivation, it was necessary to perform it under sedation or anaesthesia, ie, in the operating theatre so the background noise masking effect would become effective, as Lins et al,<sup>12</sup> Rickards et al,<sup>10</sup> or Savio et al<sup>11</sup> point out.

Although our study does not generally differ much from those of other authors, small differences between authors can be observed (Table 2).

The differences for healthy adults in the estimates by Dimitrijevic et al<sup>13</sup> were 14 (11) and 5 (9) dB HL, on the other hand for Lins et al<sup>12</sup> they were 14 (11) and 12 (11) dB SPL, and for Aoyagi et al<sup>15</sup> 29 dB HL on average. In the studies performed on pathological adults, for Pérez-Ábalo et al<sup>16</sup> they would be around 13 and 7 dB SPL for the 500 and 1000 Hz frequencies, respectively. In the studies performed on children, Lins et al<sup>12</sup> found a margin of error of 45 (13) and 29 (10) dB SPL and of 58 (12), and 43 (14) dB SPL, depending on the background noise with which the exams were performed. Savio et al<sup>11</sup> describe differences of 23 (10) dB SPL in left ears and 22 (12) dB SPL in the right for the 500 Hz carrier signal and 20 (12) dB SPL in the left ears, and 19 (13) dB SPL in the right for the 1000 Hz carrier signal. For Rickards et al<sup>10</sup> the differences for this population would be found between 53 (10) and 31 (8) dB SPL for the 500 and 1000 Hz frequencies. In the studies performed on pathological children, these differences were minimal and thus Savio et al<sup>11</sup> found differences of 12 (11) dB SPL at 500 Hz and 7 (8) dB SPL at 1000 Hz. In principle, these differences are due to:

- The different types of stimulation used: Savio et al<sup>11</sup> and Lins et al<sup>12</sup> use MF type stimulations with a single modulation in amplitude. Dimitrijevic et al<sup>13</sup> utilize the MM variety with AM (100%) and FM (25%). We



**Figure 3.** Differences in the group of pathological subjects (scale of dB HL for carrier signals at 500 and 1000 Hz, respectively). LTA indicates liminar tonal audiometry; ASSR, auditory steady state response.

have followed the methodology of Rance et al,<sup>8</sup> who used AM (100%) and FM (10%) stimuli; this type of stimulus allows, since the stimulation components are in phase, the production of responses that increase their amplitude by 50% as opposed to the 30% achieved by Dimitrijevic et al,<sup>13</sup> without interfering with other frequency areas

- The influence of the statistics used to detect response must also be pointed out. While they were all similar in efficiency for Valdés et al,<sup>17</sup> Picton et al,<sup>7</sup> who studied the different results obtained with the F test of hidden periodicity and phase weighted test with respect to CP and CMS, concluded that those based on amplitude, and phase parameters would be more sensitive than those based only on phase
- Another influencing factor is background noise, as we have previously seen
- And, lastly, in terms of the methodology used to obtain thresholds, there is currently only 1 validation study<sup>18</sup> and this refers to the Audix® equipment

We could come to the following conclusions:

- From the frequency standpoint, the use of modulated continuous tones allows us to obtain more specific responses than with clicks
- The application of FFT allows the use of statistics, which makes the technique doubly objective, as it does not require collaboration by the study subject or the examiner
- Modulation frequencies between 70 and 110 Hz give rise to responses that are originated by the overlapping of short latency responses and thus are not affected by sleep, sedation or general anaesthesia
- ASSR recordings have to be considered as an electroaudiometric method and not as an LTA in the strict sense

- There are no statistically significant differences between the thresholds registered at 500 and 1000 Hz, and those of LTA in subjects with hearing loss for these same frequencies
- There are no statistically significant differences between the estimates made by the equipment for 500 and 1000 Hz carrier signals, and the LTA thresholds in either group (with normal hearing or hearing loss)
- ASSR allows detection of hearing remnants undetected by ABR
- ASSR and click ABR are complimentary and non-exclusive examinations, as the frequency spectrum classically explored with click ABR is complemented by the electroaudiometric examination of low frequencies with ASSR

Thus, both should be used together in diagnostic protocols for the complex field of hearing loss in order to be able to optimize treatments in each case.

## REFERENCES

1. Pérez-Ábalo MC, Torres A, Savio G, Suárez EE. Los potenciales evocados auditivos de estado estable a múltiples frecuencias y su valor en la evaluación objetiva de la audición [electronic publication]. *Revista Electrónica de Audiología*. 2003;2:42-50. Available from: <http://www.auditio.com/revista/pdf/vol2/2/020204.pdf>
2. Barajas JJ, Zenker F. Potenciales evocados auditivos continuos [electronic publication]. *Revista Electrónica de Audiología*. 2002;1:20-4. Available from: <http://www.auditio.com/revista/pdf/vol1/2/010202.pdf>
3. Cohen LT, Rickards FW, Cohen LT, Clark GM. A comparison of the steady state potential to modulated tones in awake and sleeping humans. *J Acoust Soc Am*. 1991;90:2467-79.
4. Plourde G, Picton TW. Human auditory steady-state responses during general anesthesia. *Anesth Analg*. 1990;71:460.
5. Aoyagi M, Suzuki Y, Yokota M, Furuse H, Watanabe T, Ito T. Reliability of 80Hz amplitude-modulation-following response detected by phase coherence. *Audiol Neurotol*. 1999;4:28-37.
6. Kuwada S, Anderson J, Batra R, Fitzpatrick D, Teissier N, D'Angelo WR. Sources of the scalp-recorded amplitude-modulation following response. *J Am Acad Audiol*. 2002;13:188-204.
7. Picton TW, Dimitrijevic A, John MS, van Roon P. The use of phase in the detection of auditory steady-state responses. *Neurophysiologie Clinique*. 2001;112:1698-711.
8. Rance G, Rickards FW, Cohen LT, de Vidi S, Clark GM. The automated prediction of hearing thresholds in sleeping subjects using auditory steady state evoked potentials. *Ear & Hearing*. 1995;16:499-507.
9. Rance G, Rickards FW. Prediction of hearing threshold in infants using auditory steady state evoked potentials. *J Am Acad Audiol*. 2002;13:236-45.
10. Rickard FW, Tan LE, Cohen LT, Wilson OJ, Drew JH, Clark GM. Auditory steady-state evoked potential in newborns. *Br J Audiol*. 1994;28:327-37.
11. Savio G, Pérez-Ábalo MC, Valdés JL, Martín V, Sierra CE, Rodríguez E, et al. Potenciales evocados auditivos de estado estable a múltiples frecuencias: una nueva alternativa para evaluar la audición en forma objetiva. *Acta Otorrinolaringol Esp*. 1997;25:87-97.
12. Lins OG, Picton TW, Boucher BL, Durieux-Smith A, Champagne SC, Morán LM, et al. Frequency-specific-audiometry using steady-state responses. *Ear & Hearing*. 1996;17:81-96.
13. Dimitrijevic A, John MS, van Roon P, Purcell DW, Adamonis J, Ostroff J. Estimating the audiogram using multiple auditory steady-state responses. *J Am Acad Audiol*. 2002;13:205-24.
14. Ponce de León M. Potenciales evocados auditivos de estado estable a múltiples frecuencias. *Voces en el silencio*. 2001;193:1-5.
15. Aoyagi M, Kiren T, Furuse H. Pure tones threshold prediction by 80 Hz amplitude-modulation following response. *Acta Otolaryngol (Stochk)*. 1994;511:7-14.
16. Pérez-Ábalo MC, Savio G, Torres A, Martín V, Rodríguez E, Galán L. An optimized method to test frequency specific thresholds in hearing impaired children and normal subjects. *Ear & Hearing*. 2001;22:200-11.
17. Valdés JL, Pérez-Ábalo MC, Martín V, Savio G, Sierra C, Rodríguez E, et al. Comparison of statistical indicators for the automatic detection of 80 Hz auditory steady state response. *Ear & Hearing*. 1997;18:420-9.
18. Martínez-Beneito P, Morant A, Pitarch MI, García JM. Potenciales evocados auditivos de estado estable a multifrecuencia como técnica de determinación de umbrales auditivos. *Acta Otorrinolaringol Esp*. 2002;53:707-17.