USEFULNESS OF AUDITORY BRAINSTEM AUDIOMETRY IN FORENSIC MEDICINE AND EXPERTISE OF AUDITORY DISABILITIES

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Abstract: *Auditory Brainstem Response (ABR) Audiometry is widely used in diagnosing deafness in children, assessment of hearing threshold in adults, determining the type of hearing loss and detection of auditory nerve or brainstem lesions. The goal of this article is to highlight the main features of Auditory Brainstem Response Audiometry which uses the click as a stimulus, but also other stimuli with frequency specificity, like short duration tones (burst) or continuous tones (Auditory Steady State Response, ASSR). Also, we emphasize the advantages and disadvantages of the techniques used in assessing of hearing in adults who request forensic medicine services or in deaf patients who undertake auditory handicap expertise.*

INTRODUCTION

Auditory brainstem response (ABR) or Brainstem auditory evoked potentials (BAEP) is by far the most used technique in the assessment of neural response from the periphery of the auditory system towards the superior brainstem. The evoked potentials are called "early" because recording of the response occurs within the first 10 milliseconds after acoustic stimulation. ABR is technically independent of the awareness state of the patient; therefore, it can be recorded during natural or induced sleep, essential conditions for young children or multi-handicapped. ABR is an onset response and therefore, a large number of neurons have to be activated simultaneously. Clicks are commonly used stimuli for ABR.(1) Clicks have an abrupt onset, are short in duration, and have a broad spectrum. Other types of stimuli are also used for eliciting early evoked potentials such as tone burst, tone pip or chirp stimulus. During the 1990s, a new technique was developed to estimate hearing thresholds, the auditory steady state response (ASSR).

The further discussion gives an overview on the main features of the techniques used in hearing assessment with their advantages, disadvantages and usefulness in forensic and auditory expertise.

Click Auditory Brainstem Response - Click ABR

This technique is the most important part of the electrophysiological exploration, used for hearing loss assessment in children and otoneurologic diagnosis, especially for patients with asymmetric hearing loss.

The click is a stimulus of very short duration (an electric pulse of 100 µsec), with broad spectral content from 100 to 10000 Hz, but also the best stimulus in eliciting synchronous neural responses. Recording of the electrical activity occurring in the auditory nervous system shows 7 waves during the first 10 milliseconds after stimulation. The waves are labelled in order of their appearance, with roman characters. The wave V is the most robust. The smallest intensity of the stimulus that evokes the wave V has a certain value in assessing the auditory threshold, taking into consideration that the correction applied for estimating the psychoacoustic threshold of the subject is up to 10 dB.

This method is useful in the assessment of auditory threshold above 2 KHz. As mentioned above, the click is a broadband stimulus with a very short duration that generates the displacement of the entire basilar membrane and therefore it is considered non frequency specific. However, this stimulation accomplishes a good synchronous firing in the neural fibers from the base of the cochlea, providing information of the hearing level in the 2-4 kHz interval. This is no longer available in severe to profound hearing loss, where the auditory response to click stimulation might be due to basilar areas other than the ones at the base of the cochlea.

The test is relatively simple to manage, but even though it is objective, its interpretation depends on the physician's experience. Also it is worth mentioning that ABR traces may be influenced by noise.

Some artifacts are due to the patient: electrical activity of the brain (EEG), eye artifacts represented by the electric dipole of the eye (electrooculographic potentials, EOG) and activity of the extraocular muscles or electrical activity produced by skeletal muscles (EMG) and heart (ECG especially in children), but also external electromagnetic interferences, radiofrequency and electrical network interference (2). Eye movement may produce electrical artifacts of low frequency and amplitude up to 500 µV. Even during sleep, when EMG is low, EEG and EOG levels may produce low frequency, very broad artifacts. Conventional ABR is impaired by these artifacts, but compared to ASSR, it is more resistant to noise. Due to residual noise, there is no high accuracy of latencies of waves in normal hearing patients either. In deaf patients, the lack in accuracy is even higher.

Tone Burst ABR

In order to get information on the hearing level in medium-low frequency range, one may use short duration frequency-specific tones, as the tone burst or, more recently, the narrowband chirp.

Auditory evoked potentials elicited by transient tones

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are successfully used for over 30 years. It was shown in publications (3) that most of the data obtained from auditory threshold assessment has trustworthy results. The average threshold value (wave V threshold) varies between 15 and 20 dB nHL from 500 to 4000 Hz. Not all normal hearing patients have responses at 20 dB nHL, therefore normality criteria for estimated auditory threshold (in dB eHL - estimated hearing level) may be higher than 25 dB eHL. Every lab should have its own norms for applying the correction coefficient in assessment of the psychoacoustic threshold of the subject. Unlike auditory steady state response (ASSR), discussed below, tone brief stimuli ABR means recording a summed auditory neural activity with latency, amplitude and reproducibility of the wave V peak. Tone burst is a compromise between specific frequency and the short duration of the stimulus which would fire the auditory nerve fibers. The stimulus is a very short tone with an attack and release time and a very short plateau. The attack and release time can be set using a Blackman function in order to reduce spectral wideness (the energetic margins to and beyond nominal frequency). Due to the fact that, as it gets further away from the base of the cochlea, the synchronization of nervous fibers corresponding to the middle and apical areas of the cochlea is more difficult, it can be easily understood why the objective threshold of wave V needs a correction factor for estimating the psychoacoustic threshold of the subject.(4)

Taking into consideration that the ABR purpose is identifying hearing loss exceeding 25 dB HL or eHL (estimated behavioural hearing level), then applying the correction factors to the 25 dB loss may lead to different levels at which the wave V may be identified, depending on the frequency of the stimulus:(5)

- 500 Hz Tone Burst= 40 dB nHL
- 1000 Hz Tone Burst = 35 dB nHL
- 2000 Hz Tone Burst = 30 dB nHL
- 4000 Hz Tone Burst = 25 dB nHL

Chirp Auditory Brainstem Response - Chirp ABR

More recently implemented in the ABR equipment is the chirp stimulus (CE chirp, named after Claus Elberling inventor) (6), which is a modified click and can be frequency specific if this wide band stimulus is split into chirp subsets using band octave filters with central frequency which vary between 500 and 4000 Hz (frequency specific narrow band CE-chirp). The chirp stimulus is an acoustic stimulus designed to activate simultaneously all the sensory hair cells on the basilar membrane of the organ of Corti. The principle of chirp stimulation is that by modifying the click, the low frequencies are delivered first, that requires more time to activate the apical part of the cochlea compared to the high and medium frequencies that require less time to get to the maximum displacement area of the basilar membrane. It is a “swiped” manner stimulation, where low frequencies are delivered 5 milliseconds earlier than the high ones. In this case, the lower frequencies reach the apex of the cochlea at the same time the higher frequencies stimulate the base of the cochlea. In theory, both the click and the chirp activate the entire basilar membrane, but as for the click, the basal part of the cochlea which codifies high frequencies will be stimulated first, and then the rest. By this change in the presentation of the spectral compounds of the click, the entire basilar membrane responds synchronously, therefore the amplitude of the evoked response, especially at low intensities, is higher compared to the wave amplitude generated by click stimulation.

Filtering the chirp by various narrow band filters with central variable frequency from 500 to 4000 Hz, results in recording different frequency-specific responses.

Compared to click or tone burst ABR, the advantage of chirp ABR is reducing work time and better visibility of the waves. It is obvious, though, that there never is an overlap with the psychoacoustic threshold, therefore norms should be developed and correction factors should be applied for each frequency.

Auditory Steady State Response - ASSR

The Auditory Steady State Response (ASSR) is a totally different technique compared to the classic ABR. The used stimuli are continues tones with a modulated amplitude. The recording technique detects the presence of the frequency modulation in the electrical background of the brain. In other words, the evoked response is a stable repetitive phenomenon (steady state) detected by means of a statistical method in a frequency domain that repeats itself with the same frequency as the modulating frequency of the stimulus. In order to obtain reliable ASSR results, the electric activity of the brain, as well as the other noises that are part of the biological intrinsic noise of the subject, have to be minimal. Therefore, to obtain a good ratio between the signal and the noise, the patient must be entirely relaxed, so sleep becomes necessary in most of the cases. Studies in this field show that in half of the adult population tested by ASSR method, the response could not be registered because of the low signal-noise ratio, close to zero.(7) That is why ASSR remains a complimentary test, besides click ABR, in exploring child hearing and it is performed only during sleep, most often achieved by medication or anesthesia in the operating room.

When talking about the awake adult, very poor signal-noise ratio prevents detection of evoked response, therefore the test often fails. Another feature of the ASSR technique is its good correlation with the behavioural thresholds in subjects with severe and profound hearing loss. As the hearing loss is smaller, the correction that should be applied in assessing the subjective threshold is higher.

PURPOSE

The article approaches the electrophysiological testing within the objective assessment of hearing in adult patients by means of traditional Brainstem Auditory Evoked Potentials (BAEP) and the relatively new technique using continuous tones (Auditory Steady State Response, ASSR).

MATERIALS AND METHODS

The clinical observation was made on a number of 10 deaf patients who requested an objective assessment of hearing in order to quantify the degree of the hearing disability by the Evaluation Committee of Disabled People for Adults.

The patients were evaluated during the awareness state both by click and 1 kHz tone burst Auditory Brainstem Response (ABR) and by Auditory Steady State Response technique (ASSR). The equipment used was Eclipse 25 from Interacoustics and GSI Audera from Grason Stadler manufacturer. The stimulation was made by air conduction using intra-aural transducers in all cases. Recording of the response was made using a system of two channels. The grounding electrode was placed at the front, the reference electrode on the cheek and active electrodes on the mastoid M1, for the left ear and on the mastoid M2 for the right ear. Each place where the electrode was applied with conductive paste was carefully prepared using abrasive gel in order to clean the skin and obtain a good contact electrical impedance below 5 KOhms. It was used a click stimulus of rarefaction polarity with a speed of 21,1clicks per second (c/s). Each response was composed of 2000 mediated sweeps, in a time of analysis of 15 ms. The stimulation with 1kHz tone burst used the following parameters: rarefaction polarity, rate of stimulation 39,1/sec, Blackman ramping, 2000 sweeps, analysis time 15 msec. The ASSR technique used the default protocol for awake adult patients with stimulus type: Amplitude Modulated/Frequency Modulated (AM/FM), carrier frequency: 250-8000 Hz, modulation frequency: 20-200 Hz, AM modulation: 0-100%; FM modulation: 0-15%.

RESULTS

The intrinsec noise was excessive in both techniques and made difficult the recordings of potentials in all patients tested by click ABR or ASSR. A high level of biological noise, mainly represented by the brain's electrical activity and face muscle's activity, emerges from the fact that all deaf patients are unable to lie down fully relaxed because they do not understand the purpose of the test as well as the procedure requirements in order to achieve accurate recordings.

Increasing the reject of artifacts by the ABR analysis system allowed however recording acceptable electrophysiological traces with the possibility to identify the wave V elicited by click stimulation at 90 dB nHL in two cases and at 100 dB nHL in one case. The lack of any evoked response was noticed in 6 deaf patients. The ASSR trials showed noise acquisition in 9 cases. Higher ASSR thresholds compared with those elicited by click ABR was encountered in one case.

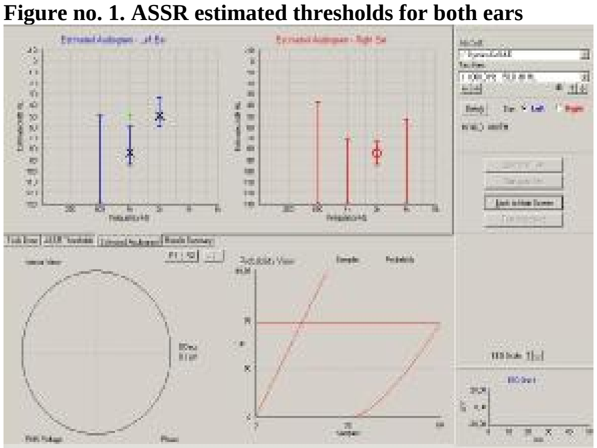
Below is presented the case of a pacient with bilateral hearing loss who underwent objective assessment in awake state. The objective assessment included both methods, ASSR (with GSI Audera) and click ABR (with Interacoustics Eclipse 25).

The acoustic parameters used for ASSR were continuous tones with frequency modulation at 46 Hz while those for ABR were short clicks with 20,1 c/sec stimulation rate, presented in rarefaction polarity.

It is noticed that electrical noise of the patient disturbed the recording of evoked response in ASSR analysis method comparing with click ABR technique.

In the right ear the auditory steady state response (figure no. 1) was absent at 4 kHz but present at 2 kHz with an estimated threshold at 80 dB HL which was not consistent with ABR results revealing a click threshold at 50 dB nHL (figure no. 2).

Figure no. 1. ASSR estimated thresholds for both ears



At the left ear the click ABR threshold was obtained at 40 dB nHL (fig. 3) in comparison with ASSR at 2 kHz which estimated a threshold at 50 dB HL (figure no. 1).

Besides the estimation of hearing thresholds in frequency domain from 2 to 4 kHz, the analysis of ABR morphology shows an increase in latency of Jewett waves which is relevant for a conductive hearing loss pathology.

Figure no. 2. Click ABR traces for left ear: objective threshold at 40 dB nHL

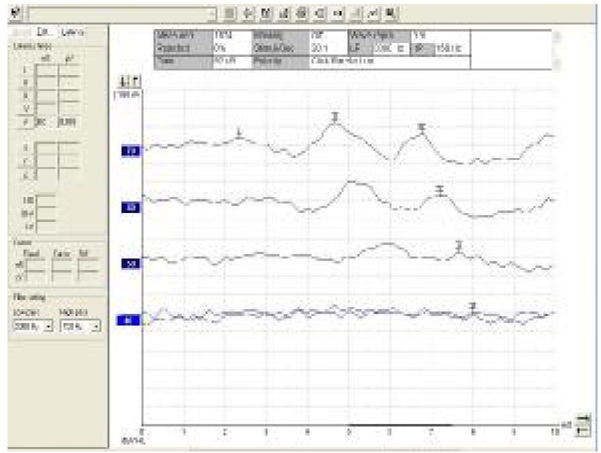
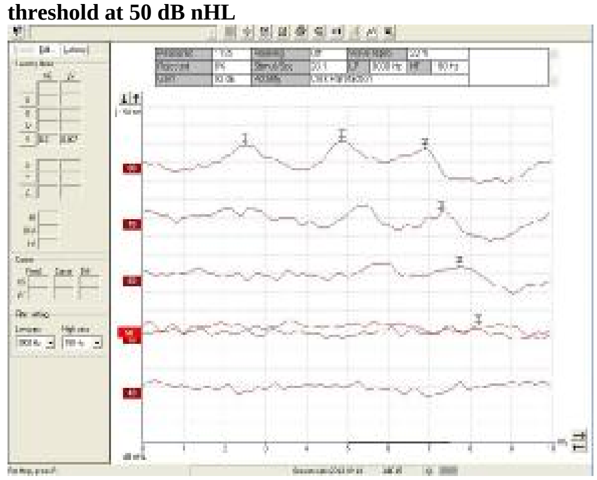


Figure no. 3. Click ABR traces for right ear: objective threshold at 50 dB nHL



DISCUSSIONS

Knowing that both click ABR and ASSR need equipment and protocols that share the same basic principles, the similarities and differences between the two techniques may be summarized as follows:

Similarities:

- both need auditory stimuli that stimulate the auditory system up to the superior part of the brainstem, although there are some studies showing that ASSR generators are not entirely identified;
- both record bioelectrical responses from the scalp, but there is a different response analysis method;
- both techniques can be contaminated by noise from the patient and external interferences.

Differences between click-, chirp- ABR and ASSR:

- click ABR stimuli have a short duration and are successively presented at a lower stimulation rate, as for ASSR uses continuous tones, modulated in amplitude;
- the evoked response is time analyzed in click ABR, while in ASSR, electrical activity is frequency analyzed;
- click ABR shows the waveform in a time-based domain and depends on the subjective interpretation of the examiner; ASSR is based on statistical analysis of the response probability within a confidence interval of 95% and it is an automatic response detection;

- click ABR is measured in microvolts, while ASSR in nanovolts;
- click ABR is less sensitive to noise, while for ASSR there should be a much lower noise level which can happen only by putting the patient asleep;
- chirp ABR generates a high amplitude wave, so the examination time reduces compared to ASSR recording.

CONCLUSIONS

The purpose of this article is to highlight how the evoked potential technique used for assessing auditory threshold has several variants, depending on the used stimulus, each having its own advantages and disadvantages.

The ASSR remains an electrophysiological technique dedicated for estimation of auditory thresholds in infants and young children under anesthesia.

As for patients who do undertake forensic expertise or auditory handicap expertise, auditory evoked potential tests with specific stimuli like tone burst of chirp may be more successfully done while the patient is awake. Unlike these, ASSR is more sensitive to noise and may be unrecordable while examining the awake patient, therefore, the test which would give a trustworthy result in estimating hearing thresholds should remain the audiologists' decision.

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