Comparison between auditory steady-state responses and pure-tone audiometry

Poređenje metode određivanja *steady-state* auditivnih evociranih potencijala i tonalne liminarne audiometrije

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Abstract

**Background/Aim.** A more recent method, the auditory steady-state response (ASSR), has become more and more important test method due to difference that was found in previous investigations between hearing thresholds determined by the ASSR and the pure-tone audiometry (PTA). The aim of this study was to evaluate the reliability of the ASSR in determining the frequency specific hearing thresholds by establishing a correlation between the thresholds determined by PTA, as well as to evaluate the reliability of ASSR in determining the hearing threshold with respect to the level of hearing loss and the configuration of the PTA findings.

**Methods.** The prospective study included 46 subjects (92 ears) which were assigned to groups based on their level of hearing loss and audiometric configuration. All the subjects underwent determination of hearing thresholds by PTA and ASSR without insight into their previously obtained PTA results.

**Results.** The overall sample differences between the ASSR and PTA thresholds were 4.1, 2.5, 4.4, and 4.2 dB at 0.5, 1, 2, and 4 kHz, respectively. A high level of correlation was achieved in groups with different configurations of PTA findings. The correlation coefficients between the hearing thresholds determined by ASSR and PTA were significant in subjects with all levels of hearing loss. The differences between hearing thresholds determined by ASSR and PTA were less than 10 dB in 85% of subjects (ranging from 4 dB for moderately severe hearing loss to 7.2 dB for normal hearing).

**Conclusion.** The ASSR is an excellent complementary method for the determination of hearing thresholds at the 4 carrier frequencies, as well as determination of the level of hearing loss and the audiometric configuration.

Key words:
audiometry; hearing loss; audiometry, evoked response; evoked potentials, auditory, brain stem; acoustic impedance, tests; diagnosis.

Apstrakt

**Uvod/Cilj.** Metoda određivanja *steady-state* audiovinskih evociranih potencijala (ASSR), postaje sve važnija test metoda zbog razlike u pragu sluha koja je nađena u ranijim istraživanjima merenjem pomoću ASSR i tonalne liminarne audiometrije (TA). Cilj ove studije bio je procena pouzdanosti ASSR u određivanju frekventno specifičnog praga sluha određivanjem korelacije između ASSR i TA, kao i procena pouzdanosti ASSR u određivanju praga sluha u odnosu na prag sluha i konfiguraciju nalaza TA. **Metode.** U prospektivnu studiju bilo je uključeno 46 ispitanika (92 uva) koji su bili podeljeni u grupe prema njihovom nivoa slušnog oštećenja i konfiguraciji audiometrijskog nalaza. **Rezultati.** U ukupnom uzorku razlika između ASSR i PTA iznosila je 4,1; 2,5; 4,4 i 4,2 dB na 0,5; 1, 2 i 4 kHz, respektivno. Visok nivo korelacije postignut je u grupi sa različitim konfiguracijama audiometrijskog nalaza. Razlika između praga sluha određenog ASSR i TA bio je manja od 10 dB kod 85% ispitanika. **Zaključak.** ASSR je odlična komplementarna metoda za objektivno određivanje praga sluha na četiri noseće frekvencije, i zajedno sa drugim dijagnostičkim metodama predstavlja korisno oruđe za preciznije određivanje praga sluha.

Ključne reči: audiometrija; sluho, parcijalni gubitak; audiometrija, evocirana reakcija; evocirani potencijal imoždanog stabla, audiotorni; akustička impedanca, testovi; dijagnoza.

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Introduction

Although objective diagnostic methods tend to dominate modern medical science, behavioral pure-tone audiometry (PTA) remains the golden standard for identifying hearing threshold levels. With all other objective audiological methods, the main goal – reconstruction of tonal audiometry findings and identification of frequency specific hearing thresholds – is achieved with more or less success. Since the 1980’s, high quality identification of hearing thresholds within the range of speech frequencies has been achieved by various methods of auditory evoked potentials. Since then, determination of hearing thresholds has been made much easier in patients by which valid tonal audiometry could not have been previously performed, such as infants and those unable or unwilling to participate in traditional behavioral tests.

The most commonly used clinical method is auditory brainstem response (ABR) characterized by high wave reproducibility and responses that do not depend on state of consciousness. The main limitation of click-evoked ABR is inability to determine the frequency specific hearing thresholds which are required in most of the cases. The ABR hearing threshold determination is based on average hearing threshold estimation within 2–4 kHz range, i.e. determining one spot on the audiogram without the possibility of PTA configuration reconstruction. In infants, the determination of hearing thresholds up to 2 kHz is mainly based on behavioral estimation of their remaining hearing range. Attempts to compensate for this ABR shortcoming by the use of tone-evoked ABR has never been established in everyday clinical practice because it has unfamiliar waveform morphology, it is time consuming and there are no responses in cases of severe and profound hearing loss. Some studies also questioned the frequency, specificity and reliability of threshold estimation in the low frequency tone pip range.

A more recent method, the auditory steady-state response (ASSR) has become more and more important as an alternative to objective audiometry. In contrast to ABR in which stimuli are broadband clicks or tone bursts, the ASSR is evoked by using continuous amplitude modulated and frequency modulated tone. Due to stimuli characteristics, ASSR is performed binaurally at 4 frequencies: 0.5, 1, 2, and 4 kHz, simultaneously. The obtained response after being processed by an objective, sophisticated, statistically based mathematical detection algorithm gives us information on the hearing threshold at the 4 given frequencies.

During the last couple of years, several studies investigated clinical application of ASSR as an objective audiometry method. Most studies agree that there is a significant correlation between hearing thresholds determined by the ASSR and the PTA, but the difference was found to be between 4–34 decibel (dB). The greatest difference in hearing thresholds is found in patients with normal hearing, while it was significantly smaller in patients with sensorineural hearing loss.

In the light of this discrepancy, the aim of this study was to evaluate correlations between the hearing thresholds determined by ASSR and PTA in subjects with different level of hearing loss as well as with different audiometric finding configurations.

Methods

The study protocol was approved by the local Ethics Committee. Informed consent was required for every subject before they could participate.

The study group comprised of 46 subjects (92 ears), aged 15–75 (mean age 48 years): 26 females and 20 males. All subjects underwent an otoscopic examination, a tympanometry, a PTA, and an ASSR.

Only the subjects with normal otoscopic and tympanometric findings were included in the study. Patients with conductive and mixed hearing loss were excluded from further study.

Audiologic examinations were conducted in double sound isolation booths. Clinical audiometer Madsen OB 822 was used for the PTA. Pure-tone air conduction stimuli were presented to the test ear via a set of TDH-50P headphones. The B71 bone-conductor was used for presentation to the mastoid process. Tonal audiometry was used to measure the air conduction threshold at the octave frequencies between 125 and 12,000 Hz in 5 dB steps, using a standard procedure. Bone-conduction thresholds were measured at 500–4,000 Hz using the same procedure. In accordance with the level of their hearing loss, subjects were classified into the following groups: normal, with hearing level (HL) loss (< 15 dB HL) – 32 ears, slight (16–25 dB HL) – 18 ears, mild (26–40 dB HL) – 16 ears, moderate (41–55 dB HL) – 11 ears, moderately severe (56–70 dB HL) – 14 ears, and severe (71–90 dB HL) – 1 ear. The sample comprised of 24 ears with low frequency loss, 26 ears with high frequency loss and 42 ears with flat PTA configuration.

The ASSR measurements were conducted using an Interacoustics ASSR device. During the examination, subjects were supine and a stimulus was presented via inserted earphones calibrated at hearing level. Stimuli were 0.5, 1, 2, and 4 kHz modulated tones with 40 kHz modulation rate. This modulation rate has been chosen because in 2002, Cone-Weston et al., showed that the best results are obtained in adults using this modulation rate. Registration electrodes were placed on both mastoids (Reference), at the hair-line (Active), and on the low forehead (Ground). Impedance for all electrodes was 3 kOhm, or less.

The investigator who performed ASSR had no insight into hearing threshold determined by means of PTA, so the measurement was undertaken using the intensity higher than the anticipated one, followed by intensification at 5 dB increments. The lowest stimulus intensity at which ASSR response was registered for the given frequency was accepted as an ASSR hearing threshold.

After the PTA and the ASSR measurement, the results for each subject were compared and statistically evaluated. Following the statistical analysis, the results were considered to be significant when p value was less than 0.05.

Results

Table 1 demonstrates mean values for the entire sample by 0.5, 1, 2, and 4 kHz frequencies. It is found that the difference in mean PTA and ASSR values is lowest at 1 kHz frequency (2.5 dB), while at the other three frequencies, the difference is approximately 4 dB.

In 24 ears characterized by low frequency loss, Pearson coefficient was between 0.86 (4 kHz) and 0.97 (2 kHz). In 26 ears with high frequency loss, the correlation coefficient was between 0.88 (0.5 kHz) and 0.97 (2 kHz). However, in 42 ears with the flat PTA configuration, it was between 0.91 (0.5 kHz) and 0.95 (1 and 2 kHz). There was no statistically significant difference among correlation coefficients for the whole sample.

Table 1

<table>
<thead>
<tr>
<th>Method</th>
<th>0.5 kHz</th>
<th>1 kHz</th>
<th>2 kHz</th>
<th>4 kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavioral (PTA)</td>
<td>29.8 ± 21.1</td>
<td>26.2 ± 22.6</td>
<td>28.4 ± 25.2</td>
<td>32.5 ± 25.7</td>
</tr>
<tr>
<td>ASSR</td>
<td>33.9 ± 22.9</td>
<td>28.7 ± 21.5</td>
<td>32.8 ± 21.9</td>
<td>36.7 ± 26.2</td>
</tr>
<tr>
<td>Difference</td>
<td>4.1 ± 7.1</td>
<td>2.5 ± 5.2</td>
<td>4.4 ± 6.1</td>
<td>4.2 ± 6.9</td>
</tr>
</tbody>
</table>

High standard deviation (SD) values were due to the fact that the sample comprised subjects with variable hearing threshold, ranging from normal hearing to severe hearing loss.

In the whole group of 92 analyzed ears, a correlation between hearing thresholds determined by the ASSR and the PTA was found at all 4 frequencies.

Figure 1 shows linear regression analysis of the relation between PTA and ASSR thresholds.

Fig. 1 – Linear regression analysis of the relation between pure tone audiometry (PTA) and auditory steady-state response (ASSR) thresholds

At all the 4 examined frequencies, the correlation coefficient was greater than 0.9. The high correlation coefficient level between ASSR and PTA thresholds was also found in groups with different tonal audiometry configurations.

Figure 2 shows the correlation coefficient for the PTA and the ASSR hearing threshold level with respect to the level of hearing loss.

The results show that the strongest correlation between the PTA and the ASSR hearing thresholds exist for moderate hearing loss, while the greatest deviation exists for the normal hearing and slight hearing loss. Severe hearing loss was found on one examined ear, and it was therefore excluded from the statistical analysis.

We had to determine the specific hearing thresholds by examined frequencies, as statistically significant correlation was not sufficient for PTA threshold estimation. Therefore, the differences between the mean PTA and the ASSR hearing...
thresholds were analyzed for every individual subject. The results shown in Figure 3 demonstrate that in as many as 85% of subjects, the difference between the mean PTA and the ASSR hearing level was within the tolerable range for the clinical hearing threshold evaluation – less than 10 dB. Individually, the examined differences were within range of 0–45 dB. The biggest difference was found in a subject with normal hearing threshold, at the two examined frequencies.

**Fig. 3** – Difference between mean hearing thresholds determined by pure tone audiometry and auditory steady-state response (in decibels - dB)

The difference between mean hearing thresholds determined by the PTA at 0.5, 1, 2, and 4 kHz, and by the ASSR, with respect to the level of hearing loss is shown in Figure 4.

**Fig. 4** – Mean difference between pure tone audiometry (PTA) and auditory steady-state response (ASSR) with respect to the level of hearing loss (in decibels – dB)

A slight difference was found for mild and moderately severe hearing loss, 3.9 and 4.0 dB, respectively, while at normal hearing threshold the difference between the examined parameters was greatest – 7.2 dB on average.

**Discussion**

The limitations of the objective diagnostic methods, especially the lack of ability to evaluate the frequency specific hearing thresholds will most probably become overridden by the use of the ASSR.

For the entire sample, this comprised subjects with normal hearing as well as those with different levels of hearing loss. The difference between hearing thresholds determined by PTA and ASSR ranged from 2.5 dB at 1 kHz to 4.4 dB at 2 kHz. Swanepoel et al.\(^8\), who analyzed 12 ears with moderate hearing loss, found the slightest difference of 2 dB at 1 kHz, and greatest difference at 500 Hz. The results from other studies also confirmed that the difference between the hearing thresholds ranged from 3–14 dB.

This study confirms a very high level of correlation between hearing thresholds determined by the ASSR and the PTA. Correlations found for all of the examined frequencies (0.5, 1, 2, 4 kHz) were greater than 90%. This high level of correlation was also confirmed by other recent studies\(^9,10\). Attias et al.\(^4\) found the mean correlation coefficient of approximately 0.95 regardless of a carrier frequency (ranging from 0.86 at 0.5 kHz to 0.94 at 2 kHz). Certain studies demonstrated a significant lower level of correlation at 500 Hz compared with other frequencies. This difference is most commonly found in subjects with normal hearing threshold in which the variation between hearing thresholds determined by the ASSR and the PTA is the highest.

Sample stratification by an audiometric configuration revealed no statistically significant differences between flat type, low frequency and high frequency hearing loss. In all three groups, a high level of correlation between the ASSR and the PTA thresholds was found. A strong correlation between the different audiometric configurations was also found by other authors\(^11,12\). These findings confirm hypothesis that the ASSR examination may predict configuration of audiometric findings with a very high level of cer-
demonstrate that the largest differences between the examsistent with the results reported by other authors which also within 10 dB range in all 16 subjects. These results are consistent with the normal hearing or deviation of approximately 35 dB HL in these subjects. On the other hand, subjects in which reproducible OAE response is not achieved should undergo auditory evoked potential testing in order to evaluate the level of their hearing loss.

In conclusion, the ASSR can be an excellent complementary method which together with other diagnostic methods represents a valuable tool in more precise determination of hearing thresholds.

REFERENCES


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