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Application of Tone-pip Stimuli of Different Rise-times for Wave V Identification in Auditory Brainstem Responses (ABR) Procedures

GRZEGORZ J. HATLIŃSKI[1,*], KRZYSZTOF KOCHANEK[2], ADAM PIŁKA[2], WANDA BOCHENEK[1]

[1] *Otolaryngology Department, Stomatology Division, Medical University of Warsaw, Warsaw, Poland*
[2] *International Center of Hearing and Speech of the Institute of Physiology and Pathology of Hearing, Kajetany, Nadarzyn, Poland*

Application of tone-pip stimuli of elongated rise-times in examination of auditory brainstem responses (ABR TON) makes it possible to detect desynchronization of auditory nerve fibers in a much earlier stage of retrocochlear pathology than it would be possible when applying click-type acoustic stimuli. However, longer rise-time deteriorates synchronization of responses from individual nerve fibers. It makes the assessment of ABR morphology more difficult, in particular it hinders correct recognition of wave V. The quality of ABR recordings might be poor when examining retrocochlear pathologies, and/or in presence of excessive artifacts. The authors propose that, in the cases when accurate evaluation of wave V in ABRs recorded with the use of long-rise tone-pip stimuli (ABR TON, 4 or 8 cycles rise-time) is difficult, one should apply tone-pip stimuli of shortened rise-time (ABR TON-2, 2 cycles rise-time) to correctly identify wave V.

K e y w o r d s: biomedical measurements, auditory brainstem responses (ABR), tone-pip

1. Introduction

Application of tone-pip stimuli of elongated rise-times in examination of auditory brainstem responses (ABR TON), thanks to narrower band stimulus, enables more sensitive detection of disorders in synchronization of nerve VIII fibres than in case of application of click-stimulus [1, 3, 4, 6, 7]. Such a procedure of stimulation makes it possible to diagnose the retrocochlear pathology in the early stadium. Currently recom-

* Correspondence to: Grzegorz J. Hatliński, Otolaryngology Department, Stomatology Division, Medical University of Warsaw, ul. Stępińska 19/25, 00-739 Warsaw, Poland, e-mail: hatlinski.j@ergonet.pl
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mended tonal stimulation procedure called ABR TON with the stimulus rise-time of 4 cycles for 1000 Hz and 8 cycles for 2000 Hz and 4000 Hz and a stimulus intensity of 90 dB nHL [2, 5], in the result of rise time elongation, improves response frequency specificity as well as increases nerve VIII fibres synchronization disorders sensitivity in comparison to application of the click-stimulus, although simultaneously decreases individual auditory nerve fibres synchronization response. Decrease of synchronization results in lower amplitude of the response, its greater width and prolonged latency of wave V. The decrease of synchronization also reduces auditory brainstem response repeatability and negatively increases effect of artifacts, muscular in particular, on auditory brainstem response morphology quality. Identification of wave I and wave III is frequently impossible, also due to longer lasting artifact of the stimulus.

The greatest difficulties in the wave V identification in practical realization of the tone-pip stimuli of elongated rise-times procedure, particularly in retrocochlear pathology, are a result of wave VI and VII occurrence, with amplitudes frequently higher than the wave V amplitude as well as considerably greater effect of artifacts on auditory brainstem response morphology quality than in case of the click ABR or other stimulus of wider band and shorter duration. ABR TON data analysis is based on assessment of the wave V presence, latency and interaural latency difference of wave V (IT5).

Identification of wave I and III is impossible at most of subjects. In case of abnormal morphology (Fig. 1) other waves occur frequently, among others wave VI and VII with similar or higher amplitude which make proper identification and assessment of the wave V latency difficult.

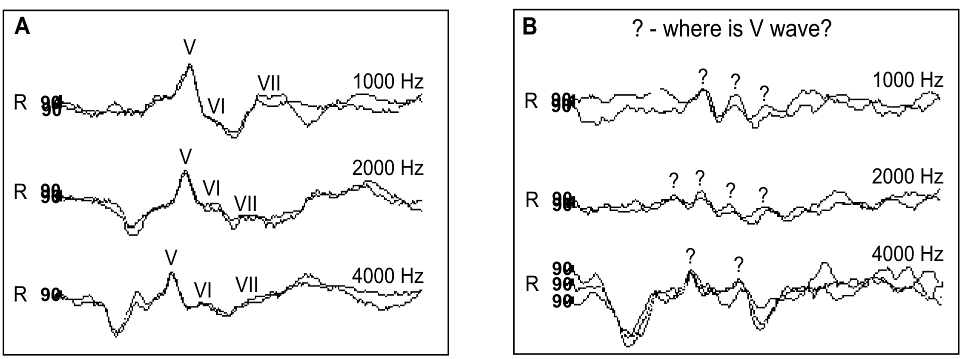

Fig. 1. Example of normal (A) and abnormal (B) ABR TON recording morphology

2. Purpose and Method

Pivotal purpose of the study was to assess usefulness of application of the tone-pip stimuli of shorter rise-time (2 cycles) and intensity of 90 dB nHL in order to identify wave V elicited by the tone-pip stimuli of longer rise-time (4 and 8 cycles) and intensity of 90 dB nHL. Shorter stimulus rise-time effects in better auditory nerve fibres synchronization and thus induces greater wave V amplitude, especially in relation to wave VI and VII. Furthermore, wave V has a smaller width and shorter latency than in case of ABR TON method stimulation (Fig. 2).

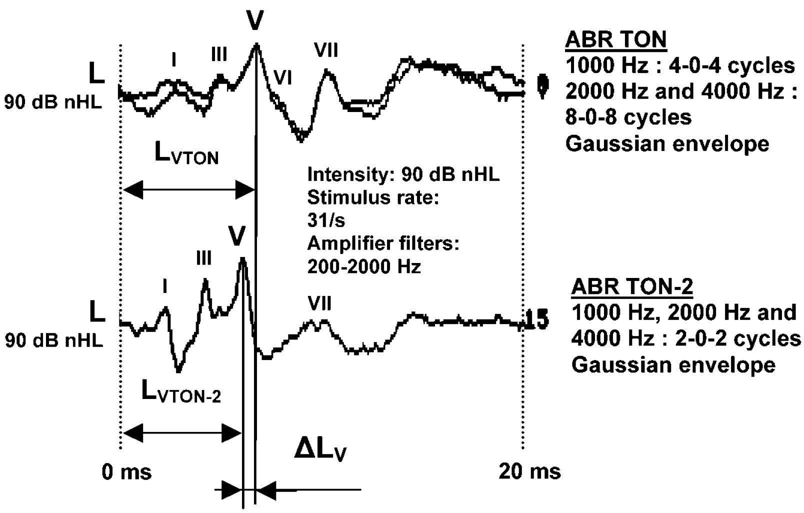

Fig. 2. Idea and method parameters

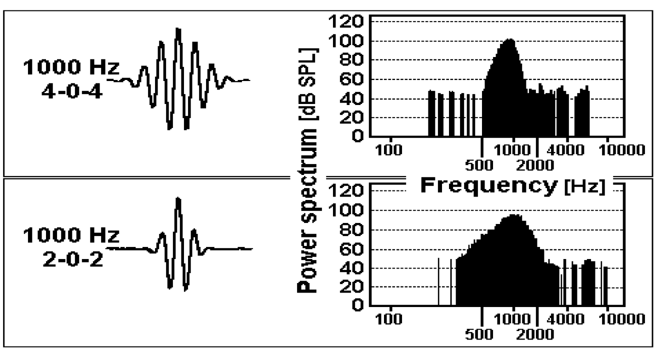

Fig. 3. Example of time course and acoustic stimulus power spectrum at frequency of 1000 Hz and two different stimulus rise-times

Basic disadvantage of stimulation method with shorter rise-time stimulus is worse ABR frequency sensitivity which results from broader band of acoustic stimulus power spectrum (Fig. 3). Tonal stimulation method using stimulus of shortened rise-time, as opposed to ABR TON, was called by authors ABR TON-2. Usefulness criterion of the ABR TON-2 method for identification of wave V evoked by the ABR

TON method was mutual relation of the wave V latency value at two different rise-times and definite tonal frequency (1000 Hz, 2000 Hz and 4000 Hz). This mutual relation, marked on Fig. 2 as ΔL_V and defined by formula (1) was called by authors the interlatency difference – it represents the difference between latency of wave *V* evoked by the ABR TON method (L_{VTON}) and latency of wave *V* evoked by the ABR TON-2 method ($L_{VTON\text{-}2}$).

$$\Delta L_V = L_{VTON} - L_{VTON\text{-}2} \tag{1}$$

3. Material and Results

Verification of the ABR TON-2 method usefulness was carried out on over 80 subjects (50 women, 30 men) aged from 17 to 67 with healthy ears (norm, 30 subjects) or with perceptive hearing loss of different type and degree (30 subjects with the cochlear hearing loss, 20 subjects with the retrocochlear hearing loss). The subjects underwent tone-pip stimulation at intensity of 90dB nHL and frequency of 1000 Hz, 2000 Hz and 4000 Hz and of two different stimulus rise-times, with amplitude modulated by a Gaussian function, for each frequency – 2 and 4 cycles for 1000 Hz and 2 and 8 cycles for 2000 Hz and 4000 Hz (Fig. 2). The error of the wave *V* latency measurement was 0.04 ms (milliseconds).

Table 1. Mean values and standard deviation for the normal hearing subjects

Frequency	1000 Hz	2000 Hz	4000 Hz
L_{VTON}	7.52 ± 0.35 ms	7.03 ± 0.30 ms	6.37 ± 0.27 ms
$L_{VTON\text{-}2}$	6.84 ± 0.28 ms	6.18 ± 0.26 ms	5.91 ± 0.23 ms
ΔL_V	0.68 ± 0.16 ms	0.85 ± 0.15 ms	0.45 ±0.13 ms

The significance level $\alpha < 0.05$.

Table 2. Mean values and standard deviation for the subjects with the cochlear hearing loss

Frequency	1000 Hz	2000 Hz	4000 Hz
L_{VTON}	7.68 ± 0.31 ms	7.16 ± 0.23 ms	6.61 ± 0.32 ms
$L_{VTON\text{-}2}$	6.98 ± 0.25 ms	6.29 ± 0.22 ms	6.05 ± 0.26 ms
ΔL_V	0.70 ± 0.17 ms	0.87 ±0.14 ms	0.56 ± 0.14 ms

The significance level $\alpha < 0.05$.

Table 3. Mean values and standard deviation for the subjects with the retrocochlear hearing loss

Frequency	1000 Hz	2000 Hz	4000 Hz
L_{VTON}	8.27 ± 0.46 ms	7.98 ±0.56 ms	7.66 ± 0.36 ms
$L_{VTON\text{-}2}$	7.74 ± 0.36 ms	7.11 ± 0.43 ms	7.11 ± 0.36 ms
ΔL_V	0.53 ± 0.15 ms	0.87 ± 0.20 ms	0.55 ± 0.17 ms

The significance level $\alpha < 0.05$.

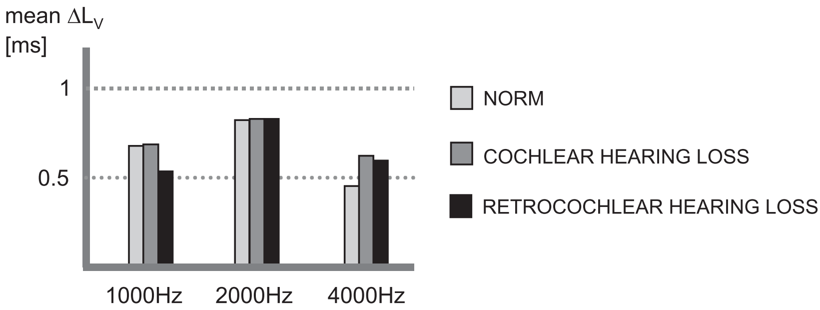

Fig. 4. Mean values ΔL_V for 1000 Hz, 2000 Hz and 4000 Hz for the normal hearing subjects and for the subjects with cochlear and retrocochlear hearing loss

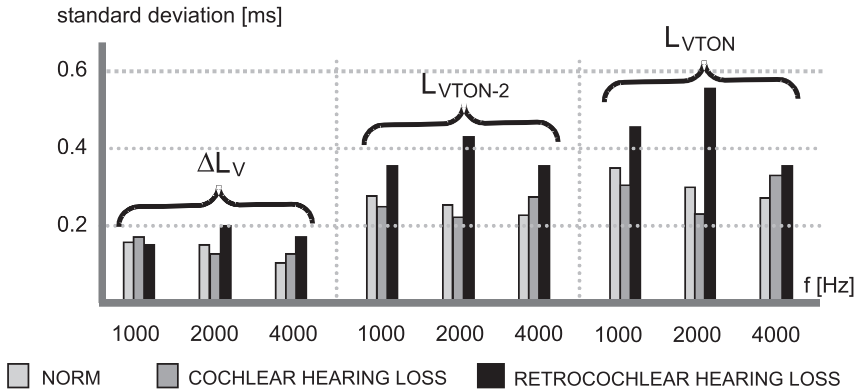

Fig. 5. Standard deviations ΔL_V, L_{VTON} and $L_{VTON\text{-}2}$ for 1000 Hz, 2000 Hz and 4000 Hz for the normal hearing subjects and for the subjects with cochlear and retrocochlear hearing loss

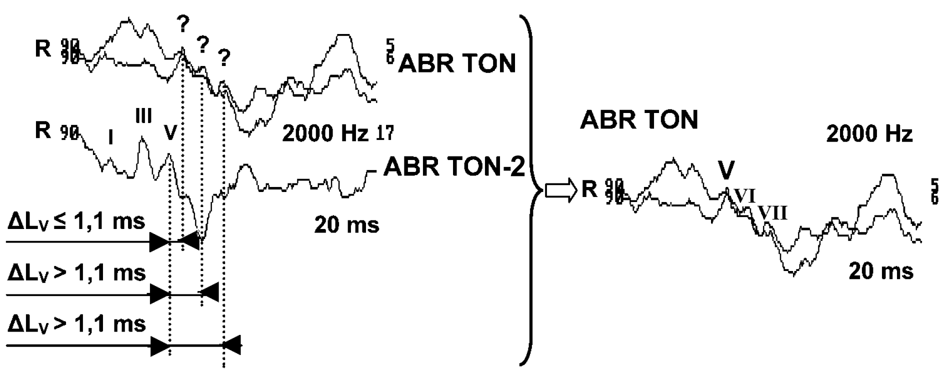

Fig. 6. Example of the wave V identification by means of the ABR TON-2 method

Results presented in Table 1, Table 2, Table 3, and in diagrams in Figure 4 and Figure 5 indicate that the interlatency difference (ΔL_V) doesn't exceed 1 ms as a rule. Standard deviation of the interlatency difference (ΔL_V) is lesser than standard deviation of the wave *V* latency for both methods. It is one of the arguments for the ABR TON-2 method usefulness. Regardless of the stimulus frequency and ears state of the examined subjects, experimentally established boundary value ΔL_V amount to 1.1 ms.

Figure 6 presents an example of the correct wave *V* identification. According to boundary value rule ($\Delta L_V \leq 1.1$ ms), wave *V* is the first wave, the other two ones of bigger latency were assessed as wave VI and VII.

4. Conclusions

Analysis of the results shows that regardless of pip-tones frequency and state of hearing, the difference between latencies of waves *V* for two different rise-times and equal stimulus frequency (interlatency difference) doesn't exceed 1 ms as a rule. At the same time intervals of wave V and VI as well as intervals of wave VI and VII doesn't exceed 1.5 ms in each method of stimulation as a rule. Abovementioned boundary values ΔL_V as well as time intervals V–VI and VI–VII practically exclude possibility of an incorrect wave V identification. When ΔL_V exceeds 1.1 ms, one should suspect that wave VI or VII was detected and examination should be repeated. Also, after examination by means of the ABR TON method, as the ABR recording morphology is seemingly not disordered, in case of large interaural latency difference of wave *V* (IT5) it is proper to perform the test by means of the ABR TON-2 method – e.g. wave V couldn't be disclosed because of being masked by wave VI.

The obtained results prove usefulness of test with shortened stimulus rise-time (ABR TON-2 method) for identification of wave *V* evoked in the test with elongated rise time (ABR TON method).

In case of doubt concerning presence and latency value of wave *V* evoked in the ABR TON method, the ABR TON-2 method application enables its effective identification. We recommend this test particularly in case of retrocochlear pathology suspicion as well as in case of excessive muscular artifacts and lack of subject's proper relaxation.

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