

A Comparison Between Middle Latency Responses and Late Auditory Evoked Potentials for Approximating Frequency-Specific Hearing Levels in Medicolegal Patients with Occupational Hearing Loss

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Abstract: To evaluate the medicolegal relevance of middle latency responses for objectively approximating frequency-specific hearing levels in subjects with occupational hearing loss, we compared the middle latency response with the cortical response in 22 reliable subjects who had noise-induced hearing loss and were submitting claims for compensation and 21 subjects who had noise-induced hearing loss but were exaggerating the level of this loss and also were submitting claims for compensation. Middle latency components of auditory evoked potentials, especially the time-saving 40-Hz response, seem efficient and reliable for evaluating the true pure-tone thresholds (1, 2, and 3 kHz). A good correlation exists between the 40-Hz response threshold and the slow vertex response (SVR) threshold (long latency). Both also show a fairly close correlation with behavioral thresholds in cooperating subjects. However, in most cases, the 40-Hz response is less sensitive (mode of difference, 10 dB) than is the SVR. As middle latency response audiometry is not actually a time-saving procedure in comparison with cortical evoked response audiometry and as it seems less sensitive than the SVR for approximating the true threshold, the use of middle latency response audiometry seems best limited to situations in which a control or a confirmation of the SVR is wanted. Further information about the sensitivity of middle latency response to drug effects and to subject wakefulness (specifically, whether the patient is more or less sleepy) is expected.

Key Words: cortical evoked response audiometry (CERA); electric response audiometry (ERA); medicolegal compensation; noise-induced hearing loss; objective audiometry; slow vertex responses (SVRs)

Suspicious audiometric findings seem fairly common in medicolegal patients; the prospect of material gain may promote either deliberate exaggeration of hearing loss or perhaps unconscious elevation of response criteria [1]. In a previous study [2] focused on brainstem (BERA) and cortical evoked re-

sponse audiometry (CERA), we showed that when dealing with compensation claimants with professional noise-induced hearing loss, only electric response audiometry (ERA) techniques provide a reliable threshold approximation. Speech audiometry, Stenger's test and von Békésy audiometry appear to have little value in this context. With CERA (slow vertex responses [SVR]), it was possible to define frequency-specific thresholds at 1, 2, and 3 kHz in all 23 subjects exaggerating their occupational hearing loss and in all 13 control patients with comparable noise-induced hearing loss. In non-exaggerating patients with professional noise-induced

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hearing loss, the CERA thresholds differed by a mean of 13 (1 kHz), 10 (2 kHz), and 9 (3 kHz) dB from the actual perceptual thresholds. However, long-time averaging (100–500 stimuli and more), which enhances the signal-to-noise ratio, was necessary, and this renders CERA a time-consuming procedure. Middle latency responses (MLRs) also were found to be a sensitive measure near threshold [3–5] and can be evoked with frequency-specific stimuli [6, 7].

The MLRs extend from approximately 10 to 80 msec after a tone pip (i.e., a brief burst) has been delivered to the ear. The MLR has neurogenic as well as myogenic components; however, most of what is typically viewed as an MLR is neurogenic in origin. The myogenic component constitutes, for the most part, only the postauricular muscle response, which occurs between 12 and 20 msec after stimulus onset. It can be avoided when the neck muscles are relaxed as much as possible [7]. Figure 1 illustrates a typical waveform obtained by means of middle latency response audiometry (MLRA). P_a (the first positive peak) occurs at between 25 and 35 milliseconds, and P_b (the second positive peak) appears approximately 25 msec after P_a .

A variation of the MLR is the 40-Hz response, which was described first by Galambos et al. [8]. This technique is based on the fact that the MLR is a multi-peaked response with interpeak intervals (N_a - N_b - N_c) of approximately 25 msec (see Fig. 1); note that N_a , N_b , and N_c are the first, second, and third negative peaks, respectively. Thus, at approximately 40 stimuli per second, the peaks to successive stimuli overlap and aug-

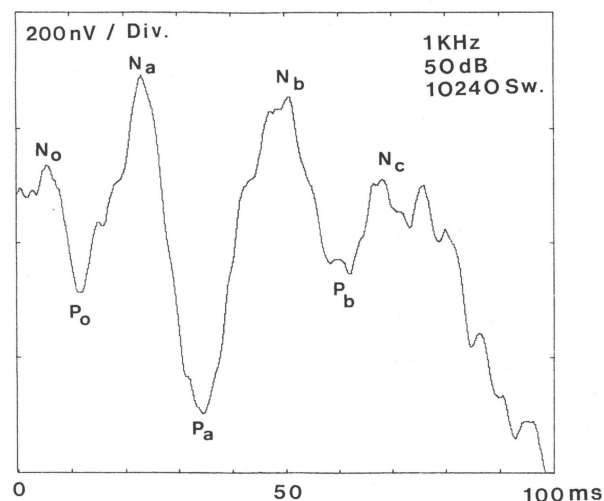


Figure 1. Typical waveform of the middle latency responses. Tone pip, 1 kHz; stimulation level, 50 dB; behavioral threshold, 15 dB. The middle latency response is a multi-peaked response with interpeak intervals (N_a - N_b - N_c) of approximately 25 msec.

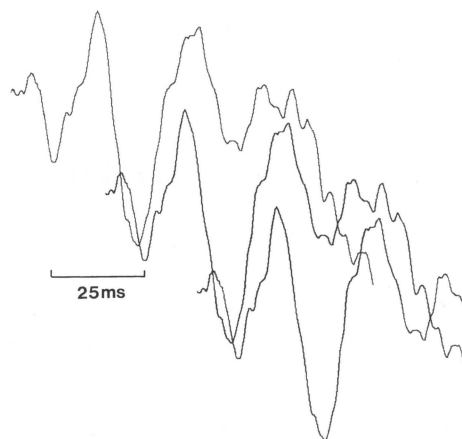


Figure 2. Middle latency response audiometry using the 40-stimuli-per-second paradigm (event-related potential). The middle latency response peaks to successive stimuli overlap and augment each other ("in-phase" addition). The signal is that shown in Figure 1.

ment each other (Fig. 2); this renders the response (resembling a sine wave of 40 Hz; Fig. 3) somewhat clearer than the regular MLR, obtained at a stimulation rate of 5 Hz. This potential has been called the *40-Hz event-related potential* (40-Hz ERP) and can be evoked with frequency-specific stimuli [7, 9]. Furthermore, the ERP is a time-saving procedure when compared with the regular MLR.

The sites of MLR generators have not been determined yet with certainty: For N_0 , P_0 , and N_a , the medial geniculate ganglion and the thalamus have been suggested, as has the inferior colliculus. In laboratory animals (e.g., cat), evidence has been given for a primary

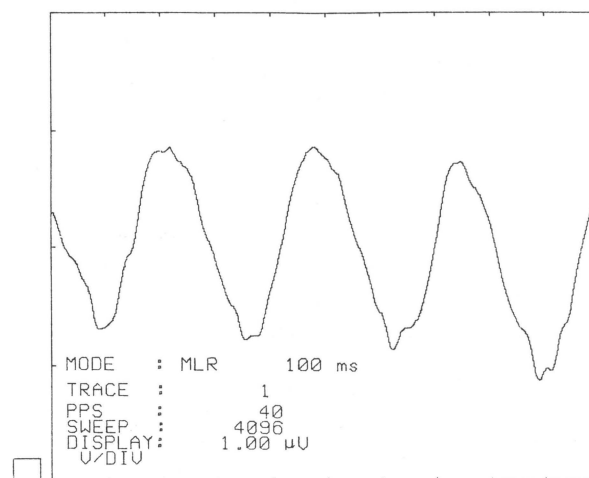


Figure 3. Event-related potential resembling a 40-Hz sine wave. (MLR = middle latency response; pps = pips per second.)

cortical origin. However, whether MLR components arise in the primary cortex in humans is somewhat uncertain [10].

To date, few published reports contain clinical results obtained with the MLR in patients with known and suspected hearing loss [10, 11]. In our study, we compare MLRs and SVRs versus behavioral hearing thresholds in subjects who have been exposed professionally to damage risk (intense noise) and are claiming financial compensation. The latter is calculated by averaging the hearing loss in decibels at 1, 2, and 3 kHz in the best ear with a weighting by the loss in the poorer ear.

The investigated subjects are separated into two groups: subjects with reliable behavioral hearing thresholds at conventional audiometric techniques and unreliable subjects suspected of exaggerating their occupational hearing loss.

MATERIALS AND METHODS

Subjects

Our study included 22 reliable subjects (24 investigated ears) who had noise-induced hearing loss and were claiming compensation (mean age, 58.2 years \pm 11.6). In addition, the study included 21 subjects (26 investigated ears) with noise-induced hearing loss who exaggerated the level of this loss and also claimed compensation.

Two ears in which neither behavioral nor ERA potential could be identified (total deafness) were eliminated. One ear had an ERP at 70 dB and no CERA response. This case is illustrated in Figure 4. In all other cases, both an SVR and an ERP could be obtained.

Exaggeration was suspected on the basis of the subjects' behavior and of results of conventional psychophysiological testing (including Békésy audiometry) and impedance audiometry (i.e., when the test-retest procedure indicated an obvious inconsistency in the responses or when the difference between behavioral threshold and acoustic reflex threshold was less than 10 dB).

MATERIALS

Both conventional and electrophysiological audiometric procedures (pure-tone audiometry, 125–8,000 Hz; air and bone conduction; test-retest; speech audiometry *casuo quo* with and without hearing aids; and impedance audiometry) were performed in a soundproof booth with a Madsen (Taastrup, Denmark) OB70 audiometer, a Madsen ZO 72 impedance audiometer, and an Interacoustics (Assen, Denmark) Békésy-audiometer.

For ERA, a Medelec (United Kingdom) Audiostar SM 273 88.1 ERA system was used with Madsen ERA

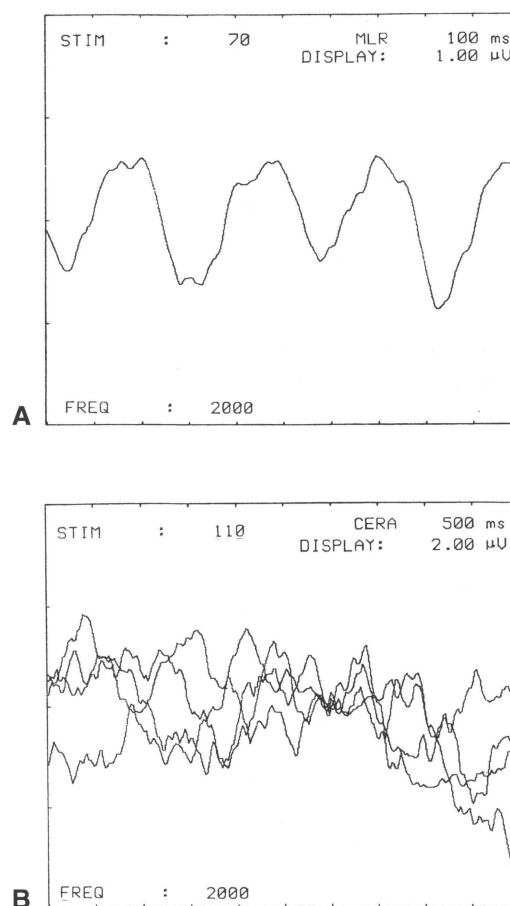


Figure 4. Rare discordance between cortical evoked response audiometry and middle latency response audiometry results. (A) Event-related potential. (B) Slow vertex response. Subject taking lorazepam daily. Eliciting an evoked potential with cortical evoked response audiometry (CERA) was not possible at a stimulus level of 110 dB (4×256 stimuli), whereas a clear sinusoidal pattern (40-Hz event-related potential) could be identified at 70 dB for the same frequency (2 kHz). (MLR = middle latency response.)

electrodes. The subject was placed in a relaxed, supine position with the head resting on pillows. To avoid muscle artifacts, minimizing neck movements was important. Wakefulness was controlled permanently.

Middle Latency Response Audiometry

The positive electrode was placed at the mastoid, and the reference was placed at the vertex. The opposite mastoid was used as the ground location. Stimuli were tone pips (2-msec rise-fall and plateau time). The repetition rate was 5 pips per second (pps) and 40 Hz, according to Galambos et al. [8]. The low filter used was 1 Hz and the high filter 300 Hz. Analysis time was 100 msec, and the sweeps numbered from 3,072 to 10,240.

Cortical Evoked Response Audiometry

Electrode placing was the same as for MLRA. Here the stimuli were tone bursts (rise time, 25 msec; plateau time, 40 msec; fall, 25 msec). The repetition rate was 1 Hz. The low filter used was 1 Hz and the high filter 30 Hz, and the analysis time was 500 msec. The number of sweeps ranged from 100 to 500.

Method

The criterion for ERA threshold was the lowest stimulus value (decibels of hearing loss, in steps of 10 dB) evoking a nondubious averaged response (i.e., the expected pattern unequivocally recognized on a superimposition of four displayed, averaged ERA traces resulting from identical stimulations; Figs. 5, 6). The average test period necessary to determine the thresholds at

three frequencies in each ear with one technique is approximately 3 hours. In our working conditions, the time necessary to define a threshold with CERA was practically the same as that with ERP.

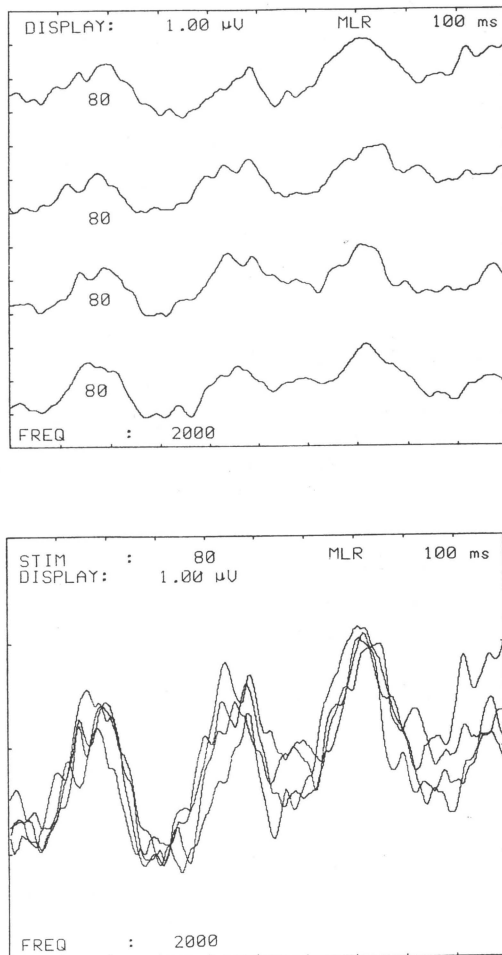


Figure 5. Test-retest reliability of a 40-Hz event-related potential (4,096 stimulations) at the electrophysiological threshold level (80 dB, 2 kHz). (MLR = middle latency response.)

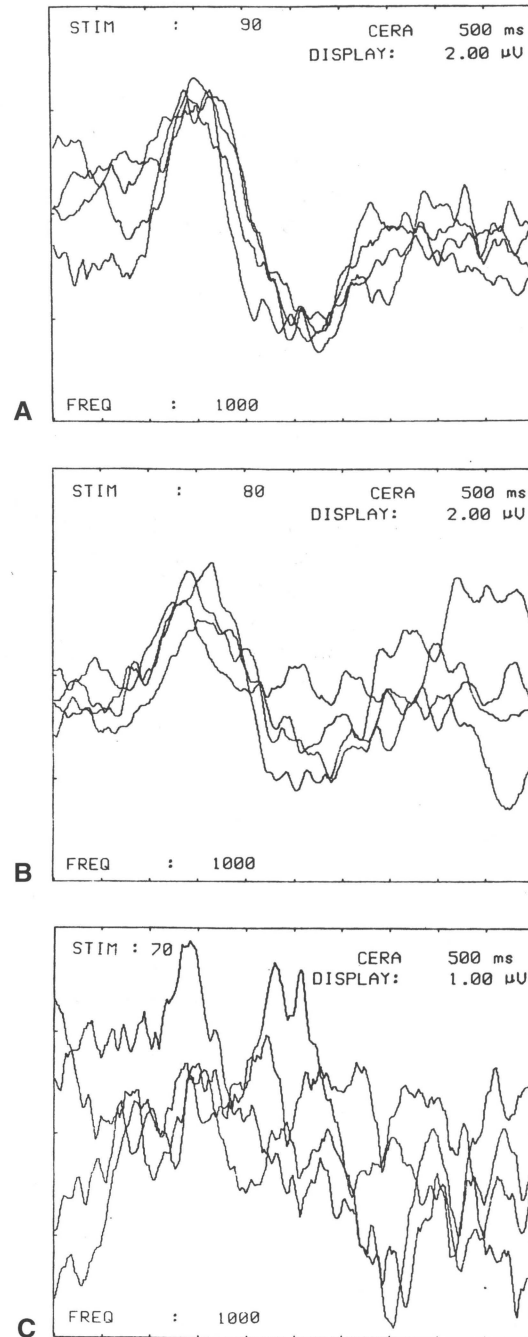


Figure 6. Procedure of threshold searching with cortical evoked response audiometry (CERA). (A) 1 kHz, 90 dB, 4×512 stimuli; (B) 1 kHz, 80 dB, 4×512 stimuli; (C) 1 kHz, 70 dB, 4×512 stimuli. In this case, a potential still can be identified at 80 dB, but at 10 dB lower, only noise is seen.

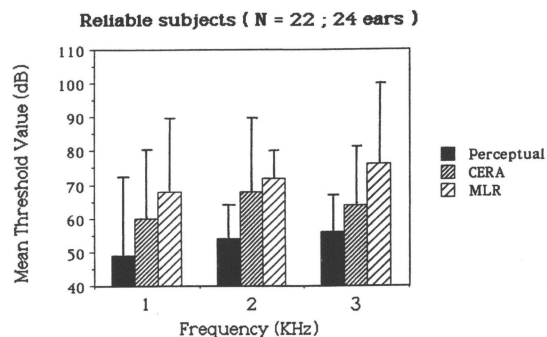


Figure 7. Mean (± 1 standard deviation) behavioral, cortical evoked response audiometry (CERA), and middle latency response audiometry (MLR) threshold values for the 22 reliable subjects, respectively, at 1, 2, and 3 kHz.

RESULTS

No statistically significant difference in age was determined between the two groups (at the level of $p = .05$). Figures 7 and 8 show plots of the mean (± 1 standard deviation) behavioral, CERA, and MLRA threshold values for the 22 reliable subjects and the 21 exaggerators, respectively, at 1, 2, and 3 kHz. Values are given in Tables 1 and 2. In Figure 9, an overview of both groups is presented, with the mean values for the three frequencies obtained with each of the three audiometric techniques.

In reliable subjects, a mean difference of approximately 11 (1 kHz), 14 (2 kHz), and 8 (3 kHz) dB is observed between the behavioral and the CERA thresholds. Further, the threshold of the MLRA is a mean of 8 (1 kHz), 4 (2 kHz), and 12 (3 kHz) dB higher than the CERA threshold.

The exaggerator group exhibited a considerable discordance between behavioral and CERA and MLRA

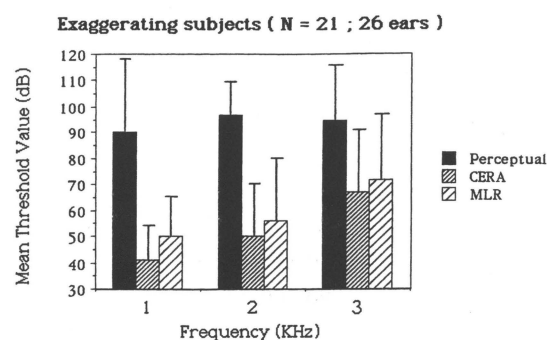


Figure 8. Mean (± 1 standard deviation) behavioral, cortical evoked response audiometry (CERA), and middle latency response audiometry (MLR) threshold values for the 21 exaggerators, respectively, at 1, 2, and 3 kHz.

Table 1. Mean Behavioral, Cortical Evoked Response Audiometry, and Middle Latency Response Threshold Values for the 22 Reliable Subjects, Respectively, at 1, 2, and 3 kHz (± 1 SD)

	Behavioral	CERA	MLR
1 kHz	49 \pm 23 dB	60 \pm 20 dB	68 \pm 21 dB
2 kHz	54 \pm 9 dB	68 \pm 22 dB	72 \pm 8 dB
3 kHz	56 \pm 11 dB	64 \pm 18 dB	76 \pm 24 dB

CERA = cortical evoked response audiometry; MLR = middle latency response.
 Note: Among the 22 reliable subjects with noise-induced hearing loss, 24 ears were tested.

thresholds, but the mean differences between the two techniques of auditory evoked potentials were 9 (1 kHz), 6 (2 kHz), and 5 (3 kHz) dB and do not differ significantly from the differences in the reliable group ($p = .05$). The mode of the difference between CERA and MLRA was 10 dB. (The electric response audiometer has intensity steps of 10 dB.)

DISCUSSION

Reproducibility of ERA Data

Near the electrophysiological threshold level, superimposition of four displayed ERA traces resulting from identical stimulations is a very appropriate method for improving pattern recognition and for decision making about the presence or absence of a response. Using this method, we found an excellent reproducibility of CERA and MLRA data. Figure 5 shows such a superimposed display for MLR just above threshold level. Figure 6 illustrates the procedure of threshold searching with CERA.

Frequency Specificity

An important advantage of CERA and MLRA is their frequency specificity. It is essential, for our purpose,

Table 2. Mean Behavioral, Cortical Evoked Response Audiometry, and Middle Latency Response Threshold Values for the 21 Exaggerators, Respectively, at 1, 2, and 3 kHz (± 1 SD)

	Behavioral	CERA	MLR
1 kHz	90 \pm 27 dB	41 \pm 12 dB	50 \pm 14 dB
2 kHz	97 \pm 13 dB	50 \pm 19 dB	56 \pm 23 dB
3 kHz	95 \pm 20 dB	67 \pm 25 dB	72 \pm 27 dB

CERA = cortical evoked response audiometry; MLR = middle latency response.
 Note: Among the 21 subjects with noise-induced hearing loss about which they exaggerated, 26 ears were tested.

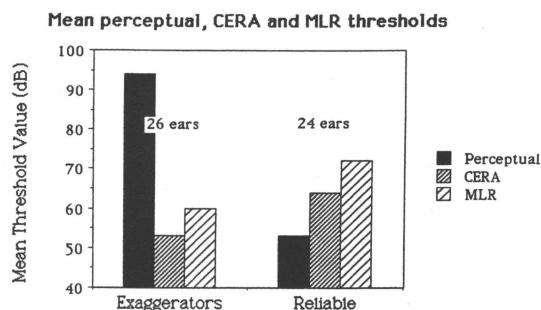


Figure 9. Mean decibel values (average, 1, 2, and 3 kHz) for perceptual, cortical evoked response audiometry (CERA), and middle latency response audiometry (MLR) thresholds in reliable and exaggerating subjects.

that the evoked potential is associated with activity from very restricted regions of the cochlear partition. With respect to the spectrum of used stimuli (90-msec tone bursts), CERA has the best frequency specificity. MLR can be evoked by tone pips, which have a relatively gradual onset and a duration of a few cycles. In these stimuli, the energy concentrates at a nominal frequency of the brief tone, and the spread of energy is reasonably narrow.

Our previous study [2] showed that, in subjects with noise-induced hearing loss (sloped audiogram), BERA thresholds correlate significantly better with CERA thresholds on 3 kHz than on 2 and 1 kHz. Click-BERA is considered to provide information about high-frequency hearing levels. Use of sophisticated techniques (e.g., masking clicks and notched-noise masking) allows improvement of frequency specificity of BERA, but the technical requirements have hampered clinical application of these techniques [10]. In this study, the typical audiometric frequency slope of occupational hearing loss is recognized also in most MLR audiograms.

Influence of Subject Attention and Wakefulness

The late components demonstrate variability associated with changes in subject wakefulness, attention, or state of consciousness [11]. Sedatives modify SVR and impose limitations on its reliability for threshold assessment [10]. The 40-Hz ERP also is reduced during sleep [10] but, unlike the later cortical responses, the MLRs have been shown to be fairly stable during changes in subject state or attention [11].

Figure 4 shows an exceptional situation in which eliciting an evoked potential with CERA was not possible at a stimulus level of 110 dB (4×256 stimuli), whereas a clear sinusoidal pattern (40-Hz ERP) could be identified at 70 dB for the same frequency (2 kHz). This subject took lorazepam daily.

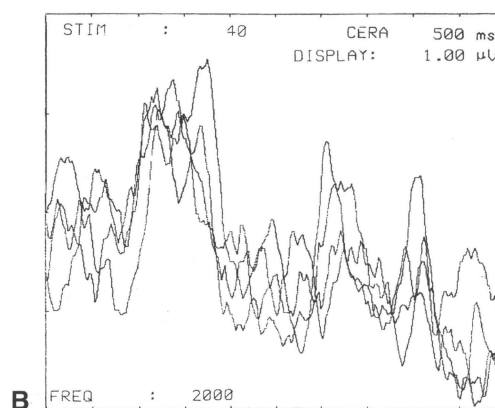
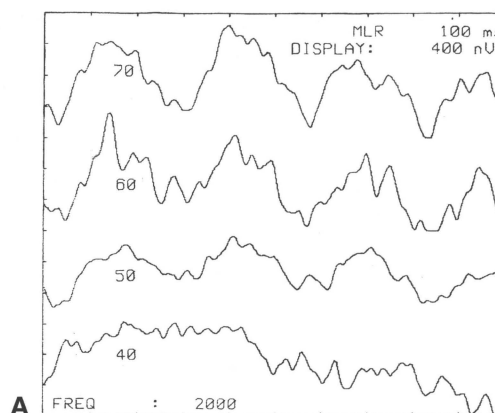


Figure 10. Most common relationship between cortical evoked response audiometry (CERA) and middle latency response audiometry (MLR) thresholds. (A) Event-related potential. (B) Slow vertex response. A clear CERA potential still is visible at 2 kHz, 40 dB, whereas with MLR, the signal (a sinusoidal wave) is absent at 40 dB but begins to emerge at 50 dB.

Difference in Threshold Between CERA and MLRA

In most cases, the difference in threshold (the mode) between SVR and ERP was 10 dB (one step in the stimulus intensity regulation). Mean values of ERP threshold in each group and for each frequency are higher than mean values of SVR threshold. Figure 10 illustrates the threshold difference between CERA and MLRA responses. A clear evoked CERA potential still is evident at 2 kHz, 40 dB, whereas with MLRA, the signal is not evident at 40 dB but begins to emerge at 50 dB.

SUMMARY

Middle latency components of auditory evoked potentials, especially the time-saving 40-Hz response, seem

efficient and reliable for evaluating the true pure-tone thresholds (1, 2, and 3 kHz) in medicolegal patients exaggerating their noise-induced hearing loss. A good correlation is found between the 40-Hz response threshold and the SVR threshold (long latency). Both also show a fairly close correlation with behavioral thresholds in cooperating subjects. However, in most cases, the 40-Hz response is less sensitive than is the SVR (mode of difference, 10 dB).

As MLRA is not actually a time-saving procedure as compared with CERA, and because it seems less sensitive than the SVR for approximating the true threshold, the use of MLRA seems best limited to situations in which a control or a confirmation of the SVR is wanted. Further information about sensitivity of MLR to drug effects and to subject wakefulness is expected.

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