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Comparison of Auditory-Evoked Potentials and Behavioral Thresholds in the Normal and Noise-Exposed Chinchilla

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Key Words. Noise exposure · Evoked response · Behavioral threshold

Abstract. Auditory sensitivity was tested in three monaural chinchillas using standard techniques and the auditory-evoked potential technique (AEP). Hearing was measured at octave steps from 500 to 8 000 Hz before, 1 day after, and 30 days after exposure to a simultaneous combination of 50 impulses (A duration = 30 μs) presented at a rate of 1/min and at 158 dB pe SPL and continuous noise (1 h of 95 dB 2–4 kHz octave band of noise).The two independent assessments of auditory sensitivity showed good agreement and the results support the use of AEP testing in experimental animals.

Introduction

The problem one faces when trying to evaluate the auditory sensitivity of experimental animals is that they are incapable of responding to verbal instructions. This is essentially the same problem as when testing young children, stroke victims and the mentally retarded. For this class of difficult-to-test patients, clinicians have traditionally used some form of conditioning audiometry, but they have recently turned to physiological indices of auditory sensitivity, e.g., electrocochleography, brain stem testing and cortical-evoked potential testing for more rapid and reliable results.

Establishing conditioned responses in experimental animals can be extremely time-consuming, and in the case of some species, totally impractical. Consequently, efficient and reliable physiological measures of hearing would be useful, especially for experiments that require a large number of subjects. Because of a favorable signal-to-noise ratio, the most popular physiological indices of auditory sensitivity have been either the cochlear microphonic (CM) recorded from the round window [*Price,* 1970] or the whole-nerve action potential (AP) [*Dallos* et al., 1978]. Unfortunately, the CM recorded in this manner has the disadvantage that it is dominated by generators in the first turn of the cochlea [*Davis* et al., 1958]. On the other hand, the whole nerve AP elicited by short-duration tone bursts has recently been shown [*Dallos* et al., 1978] to approximate the frequency-threshold curve in normal animals and in animals with mild to moderate drug-induced hearing losses. To realize the advantages of either the CM or AP measures, a recording electrode must be placed inside the middle-ear conductive system, which increases the potential for infection and tissue reaction during chronic experiments.

One alternative to the CM and AP measures of hearing is the brain stem auditory-evoked potential (AEP) recorded from chronic electrodes. In the chinchilla, a short-latency AEP can be recorded reliably and conveniently as described earlier [*Henderson* et al., 1969, 1973]. Briefly, a chronic bipolar electrode is inserted through the dura to a position over the rudimentary tentorium. The electrodes are attached to a connector which is cemented on the dorsal aspect of the animal's skull. The AEP recorded using this procedure has several advantages: (1) the preparation can be stable up to 4 months; (2) the basic acoustic characteristics of the middle ear are not disturbed, and (3) most importantly, the threshold for the AEP response approximates the behavioral measures of hearing in normal animals. However, there is some question whether the AEP is an accurate predictor of thresholds in animals with cochlear pathologies [*Trahiotis,* 1976]. The purpose behind this experiment was to determine how well the AEP thresholds agree with the behavioral thresholds when hearing is normal and when there is a significant amount of noise-induced threshold shift. To optimize the comparison, the AEP and behavioral thresholds were measured in the same animal.

Methods

3 male chinchillas (ages 2–4 years) were used as subjects. The animals were anesthetized and made monaural by surgical destruction of the left cochlea, and a chronic electrode assembly was implanted [see *Henderson* et al., 1973, for details of the procedure]. Since the paper by *Henderson* et al. [1973], the technique has been improved by using a bipolar electrode that extends from below to just above the dorsal surface of the inferior colliculus. 1 week after the surgical procedure, behavioral training using shock avoidance conditioning procedures was started.

Table I. Threshold testing schedule

Procedure	
Before exposure	
Behavioral training (BEH)	10–15 days; 1 h/day
AEP before test	3 days; 1 h/day
BEH before test	10 days; 1 h/day
Noise exposure	158-dB impulse + 2–4 kHz octave band at 95 dB SPL
After exposure	
24-hour BEH	1 h
24-hour AEP	1 h
30 day BEH	10 days; 1 h/day
30-day AEP	3 days; 1 h/day
40-day	histology

Behavioral thresholds were obtained using a shock avoidance conditioning paradigm and a modified method of limits [see *Blakeslee* et al., 1978, for details of the apparatus and training schedule]. AEP testing began at an intensity that produced a clear and unambiguous response. Then the signal level was reduced in 10-dB steps until the response was slighthly above the background noise. At this point, the intensity step was reduced to 5 dB and additional samples were collected. AEP threshold was the point midway between the highest intensity where the response was absent and the lowest intensity where the response was present. All AEP thresholds represent the consensus of two or three judges. The sequence of behavioral and AEP measurements is given in table I. The schedule was designed to minimize the extinction of the behaviour that might occur when the animal was exposed to the AEP test signals without the opportunity to respond or be shocked.

All thresholds were measured to 20-ms signals (5 ms rise/fall times) at 0.5, 1, 2, 2.8, 4, 5.6 and 8 kHz. The AEP and behavioral measurements were made in separate facilities. The calibration of the test tones was accomplished using a ½ inch microphone in the position occupied by the animal's head. Hearing loss was produced by exposing each animal to a continuous noise (95 dB SPL, 2–4 kHz) combined with impulse noise (158 dB peak-equivalent SPL, 30 μs A duration, and impulses presented 1/min). The combined exposure lasted for 1 h.

Results and Discussion

The audiograms from the 3 animals before exposure and those obtained at 1 and 30 days after exposure are shown in figures 1–3. The pre-exposure and 30-day postexposure audiograms are based on the mean of at least five behavioral measures and three AEP measures, and the audi-

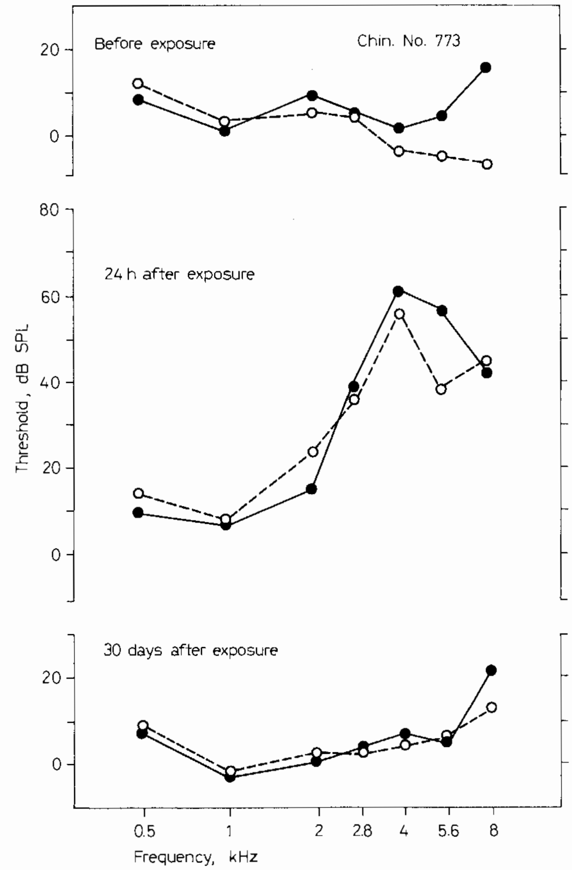

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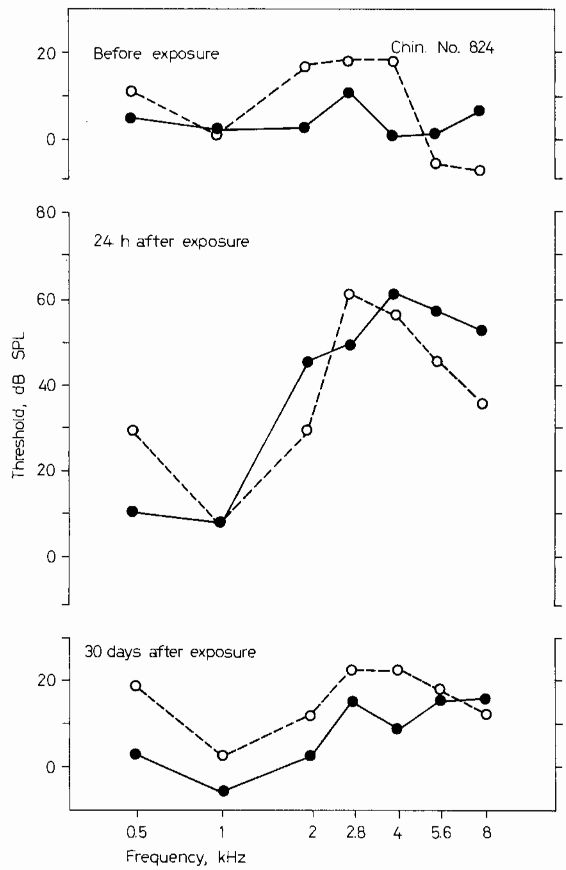
Fig. 1–3. Comparison of AEP (○) and behavioral (●) thresholds. **1** Chinchilla 773. **2** Chinchilla 824. **3** Chinchilla 753.

ograms obtained 1 day after exposure are based on one behavioral and one AEP measure. Table II presents the means and standard deviations for these measures for all subjects.

The pre-exposure audiograms show remarkably close agreement with the average thereshold difference across all frequencies and all animals being less than 0.7 dB. The two measures are actually closer together than the earlier results published by *Henderson* et al. [1973]. Also presented in table II are the results of t tests on the differences between the means for behavioral and AEP thresholds across frequency in each animal. The null



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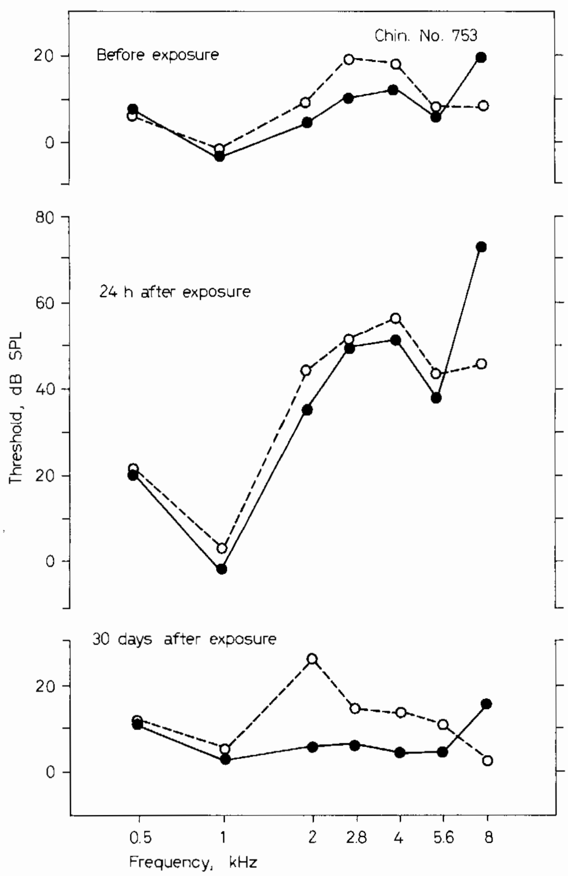
hypothesis was that the mean difference between behavioral and AEP thresholds was equal to zero. A conservative criterion ($p = 0.01$) was employed due to the use of multiple t tests and the consequent increased probability of a type I error. None of the measures (before, 24 h, or 30 days) showed any significant differences between the behavioral and AEP-collected thresholds. The concordance between the two measurements is probably the result of three factors: (1) comparison of AEP and behavioral thresholds in the same animals rather than across different subjects; (2) use of short-duration signals for both measurements, so that temporal integration of acoustic power was not a factor, and (3) improved sensitivity of the AEP procedure because of the greater signal-to-noise ratio obtained with bipolar recording electrodes.



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The audiograms obtained 1 day after exposure all show considerable elevation of threshold at 2 kHz and above and are about normal at lower frequencies. The behavioral and AEP thresholds of chinchilla 773 are in extremely close agreement. On the other hand, at some individual frequencies in chinchillas 824 and 753, differences as great as 30 dB could be found (e.g., chinchilla 753 at 24 h after exposure, 8 kHz). Such discrepancies, while unusual, are not surprising, since the 1-day postexposure data are based on only one measurement, while the pre-exposure and 30-day postexposure data are based on at least five behavioral and three AEP measurements.

Table II. Means and standard deviations for all subjects and all conditions

Animal	Exposure	Procedure		Frequency, kHz 0.5	1.0	2.0	2.8	4.0	5.6	8.0	t	p
753	before	BEH	X	7.5	–3.5	4.5	10.5	12.5	5.5	19.5	0.70	0.51
	n = 10		s	8.6	5.4	6.9	8.6	8.8	10.3	9.4		
		AEP	X	5.6	–2.0	12.3	19.3	17.7	8.0	8.3		
	n = 3		s	3.6	0.0	5.8	2.9	7.6	5.0	2.9		
	at 24 h	BEH	X	20.0	–2.0	35.0	49.0	51.0	37.0	72.0	0.03	0.98
	n = 1		s	–	–	–	–	–	–	–		
		AEP	X	21.0	3.0	44.0	51.0	56.0	43.0	45.0		
	n = 1		s	–	–	–	–	–	–	–		
	at 30 days	BEH	X	11.2	3.2	6.2	6.2	4.2	4.2	15.2	1.09	0.32
	n = 5		s	13.9	6.5	3.0	12.1	2.9	7.5	5.8		
		AEP	X	10.7	4.7	25.7	14.3	12.7	9.7	1.7		
	n = 3		s	7.6	7.6	2.9	2.9	2.9	2.9	2.9		
773	before	BEH	X	8.5	1.5	9.5	4.5	1.5	4.5	15.5	–1.60	0.16
	n = 10		s	8.2	7.8	11.8	13.3	14.9	13.3	12.6		
		AEP	X	12.3	3.0	5.7	4.3	–4.0	–7.0	–6.7		
	n = 3		s	2.9	0.0	2.0	2.9	0.0	0.0	2.9		
	at 24 h	BEH	X	10.0	8.0	15.0	39.0	61.0	57.0	42.0	–0.54	0.61
	n = 1		s	–	–	–	–	–	–	–		
		AEP	X	14.0	8.0	24.0	36.0	54.0	38.0	45.0		
	n = 1		s	–	–	–	–	–	–	–		
	at 30 days	BEH	X	7.5	–2.5	0.5	3.5	6.5	4.5	21.5	–0.59	0.58
	n = 10		s	5.6	6.0	9.0	5.6	7.2	3.0	4.7		
		AEP	X	9.0	–2.0	2.3	2.7	4.3	6.3	13.3		
	n = 3		s	5.0	0.0	2.9	2.9	2.9	2.9	2.9		
824	before	BEH	X	4.5	1.5	2.5	10.5	0.5	1.5	6.5	1.00	0.36
	n = 10		s	7.5	11.6	9.7	15.3	5.8	9.1	6.5		
		AEP	X	10.7	1.3	17.3	17.7	17.7	–2.3	–6.7		
	n = 3		s	2.9	5.8	2.9	2.9	16.1	0.6	2.9		
	at 24 h	BEH	X	10.0	8.0	45.0	49.0	61.0	57.0	52.0	–0.52	0.63
	n = 1		s	–	–	–	–	–	–	–		
		AEP	X	29.0	8.0	29.0	61.0	56.0	45.0	35.0		
	n = 1		s	–	–	–	–	–	–	–		
	at 30 days	BEH	X	3.5	–5.5	2.5	15.5	8.5	15.5	15.5	3.12	0.02
	n = 9		s	8.3	6.5	7.8	12.0	7.0	14.2	11.1		
		AEP	X	19.0	3.0	12.3	24.3	22.7	18.0	11.6		
	n = 3		s	2.9	5.0	2.9	7.6	7.6	5.0	7.6		

Values of t and associated probabilities testing the differences between behavioral and AER thresholds are included.

The 30-day postexposure audiograms of chinchilla 824 show some permanent threshold shift (PTS) at the high frequencies; however, the audiograms from the other two animals are about normal. Again both the AEP and behavioral measures reflect essentially the same level of PTS.

The initial reason for this study was to determine how well the AEP measures agree with the behavioral measures of threshold. The close agreement found in this study between the two measures when the auditory system is normal, when there is a large high-frequency hearing loss and when there is a mild loss, indicates that the AEP is a legitimate substitute for the behavioral audiogram. If one accepts the AEP as a predictor of behavioral threshold, then the AEP offers a major saving of experimental time. For example, the pre-exposure measures are based on three 1-hour AEP test periods while the behavioral data are based on 5–15 h of training plus 10 1 hour test periods. Fewer measurements are required because the AEP thresholds are less variable than those measured behaviorally.

Unfortunately, above 12–14 kHz, the AEP thresholds increase significantly and are much higher than those measured behaviorally. Thus, one cannot obtain useful information on high-frequency hearing using the AEP. However, if this high-frequency information can be sacrificed, then the AEP offers some important advantages over traditional threshold-testing procedures.

Résumé

Nous avons examiné la sensibilité auditive chez trois chinchillas par une technique comportementale et par la technique des potentiels évoqués du tronc cérébral (ABR). Les examens ont été effectués pour des espaces fréquentiels d'une octave entre 500 et 8 000 Hz, avant, 1 jour après et 30 jours après exposition des animaux pendant 1 h simultanément à un bruit continu de bande d'octave (2–4 kHz) à 95 dB SPL et à 50 impulsions de bruit (158 dB pic-équivalent, 30 μs de durée) à un rythme de 1 impulsion par minute. Jusqu'à 12–14 kHz, les résultats obtenus à l'aide des ABR concordaient bien avec ceux obtenus par la technique comportementale.

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