J Am Acad Audiol 5: 141–145 (1994)

Newborn Hearing Thresholds Measured by Both Insert and Earphone Methods

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Abstract

Auditory brainstem response (ABR) absolute thresholds were obtained from 31 ears of 28 newborns using both the insert and the earphone methods to deliver the stimuli. The two estimates on each ear were acquired in a single test session, and they differed by 10 dB or less in all cases. The results suggest that when the earphone is used, it rarely if ever collapses the ear canal to cause an artificial conductive hearing loss.

Key Words: Absolute threshold, auditory brainstem response (ABR), insert earphone, intensive care nursery (ICN), newborn

For the past 15 years, one of us (MW) has been obtaining auditory brainstem responses (ABRs) from babies about to be discharged from second and third level intensive care nurseries (ICNs) in San Diego. Year after year, close to 20 percent of the third level ICN babies have failed to respond to 30-dB clicks in one or both ears, and the comparable percentage for the second level infants has been about half this (Galambos, Hicks, and Wilson, 1982, 1984, Galambos, 1986; Galambos, Wilson, and Silva, in press). It is sometimes said that such high failure rates are due to the fact that the earphone delivering the stimulus collapses the ear canal and creates an artificial conductive hearing loss. If this explanation is correct, the hearing losses we have been reporting include an artifact of unknown magnitude, on the one hand, and, on the other, our testing staff consistently produces the artifact about twice as often when they test third level babies. After a literature search failed to uncover useful information about infant canal collapse in general and our concerns in particular, we decided to investigate the matter ourselves.

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In the study to be described here, we obtained two ABR thresholds from each ear, one by the conventional earphone method and the other by the insert procedure in which the stimulus is conducted from a distant transducer into the ear canal through a plastic tube. If the earphone produces an artificial conductive hearing loss, the two threshold estimates will disagree. We report and discuss the outcome of these measurements here.

METHOD

Subjects

ABRs were obtained from 28 infants about to be discharged from the Children's Hospital third level ICN and the Sharp Memorial Hospital and Grossmont Hospital second level ICNs (in Table 1 these are identified as N, T, and C, respectively). As part of the discharge procedure, the babies had been scheduled for the routine diagnostic ABR, which, in these hospitals, establishes whether each ear responds to 30-dB nHL clicks, and, if it does not, requires increasing the stimulus level until the threshold is reached. The insert measurement, which some clinics obtain routinely, was added to our earphone procedures to discover whether it produces lower and/or more reliable threshold estimates. The comparisons were made between August 1992 and March 1993 during sessions lasting about 1 hour. Babies

Table 1 Threshold Estimations by Subject and Method

	ABR Absolute Threshold (dB)		
*Subject Data**	*By Phone*	*By Insert*	*Difference*
32 MLT	40	35	5
32 FLN	15	5	10
33 FRN	20	10	10
33 —LC†	50	45	5
33 —RC†	50	50	0
33 FRN	20	10	10
34 FLN	10	10	0
34 —LN	15	5	10
34 —LN	10	10	0
34 FLN	25	15	10
34 FRN	20	10	10
34 ——N	5	5	0
35 —LN	20	10	10
35 —LN	15	15	0
35 —LN	35	30	5
36 MRT	30	25	5
36 MRT	30	30	0
37 FLT	30	30	0
39 ——N	15	15	0
39 MRN	15	15	0
39 —RT	35	25	10
40 MLN	15	5	10
40 MLN	35	30	5
40 —LT	35	35	0
41 MRN	20	10	10
43 FLT†	35	35	0
43 FRT†	50	50	0
— —LN†	25	25	0
— —RN†	20	10	10
— —LN	50	40	10
— MRT	40	40	0

N = Nicolet CA1000; T = Tracor Nomad 3400; C = Cadwell 5200; — = data unavailable.

*Initial numbers give conceptual age in weeks, followed by sex (M, F), ear (L, R), and ABR instrument used.

†Same baby.

who received the added insert test were not selected randomly from the group of infants (about 300) tested during this period; the ones with hearing loss by earphone were chosen whenever possible.

Procedure

The ABR testing method, already described in detail (Galambos et al, 1982, 1984; Galambos, 1986), uses a commercial device to generate the stimuli, amplify the EEG, average the ABRs, and write out the result. We used three different instruments (Nicolet CA1000; Cadwell 5200; Tracor Nomad 3400), with either a TDH 39 earphone or the Tracor Northern TM-3430-22 insert system connected to the earphone outlet. We aimed to replicate all ABRs and estimate each threshold to ±5 dB by both methods, but time often ran out before this could be accomplished. In all cases, the earphone delivering the click stimuli was hand held.

Calibrations

Each test instrument uses a 0 dB nHL reference established by a jury of normal-hearing adults. However, note that factory-supplied calibration measurements and ICN clinical measurements are made under different conditions, especially ambient noise. Furthermore, infants were tested in the ICN while asleep in an open crib, or inside an isolette, or while held in the mother's arms. Such uncontrolled variations in both test conditions and ambient noise level would not be tolerated in an audiology laboratory but are inevitable in the clinical setting. Despite the response variances they introduced, the superimposed ABR replications in Figure 1 suggest that measurement error was limited to 5 or 10 dB most of the time.

RESULTS

Since 1977, the "normal" newborn ear has been defined in our clinic as one that delivers an ABR response to a 30-dB nHL click delivered through an earphone. This definition arose out of a study that reported that 99.8 percent of 220 babies (386 ears) delivered ABRs to 30-dB clicks under an earphone, and that 47 of 50 of them also responded at 20 dB nHL but not at 10 dB (Schulman-Galambos and Galambos, 1979). The final decision to use the 30-dB suprathreshold definition instead of an absolute threshold definition was made for practical reasons: to establish the presence of a 10- or 15-dB suprathreshold response requires far less time and effort in a clinical environment, and most clinicians consider this just-suprathreshold response to be a satisfactory substitute for the nearby absolute threshold. Twenty of the 31 ears in the study were normal by this definition.

Figure 1 shows the absolute threshold estimates for two of these normal ears. Each panel displays two latency-intensity series, the one on the left made in the conventional way by holding an earphone over the pinna, the one on the right by stimuli delivered into the ear canal from the distant transducer through a plastic tube terminated in a small silicone nipple. At the bottom of each panel, the two 60-dB ABRs

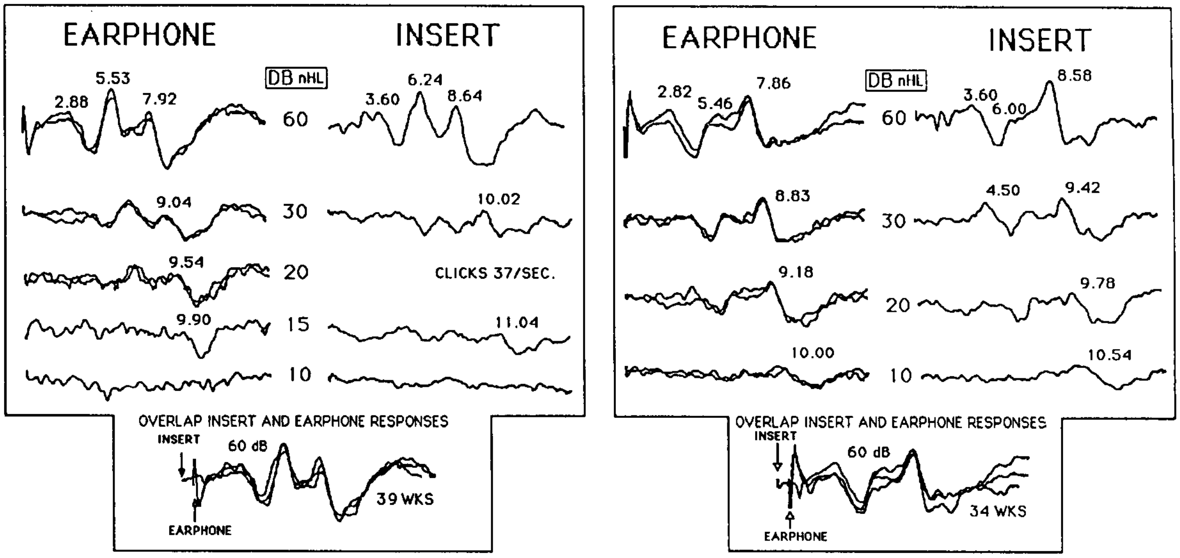

Figure 1 ABR latency-intensity series obtained from newborns aged 39 weeks (left panel) and 34 weeks (right panel) by both the earphone and the insert methods. Numbers on the traces give ABR latencies. The two 60-dB recordings in each panel are superimposed at the bottom. Both methods evoke similar physiological events at all intensity levels and agree on the intensity of the absolute threshold stimulus.

are superimposed; their similarities in morphology and latencies (each insert record has been moved to the left by 0.7 msec, the added latency introduced into the sound path by the plastic tube) indicate that the two stimulus systems delivered essentially the same nominally 60-dB level click to the eardrum. The absolute threshold estimates reached by the two methods also agree; both place this at 15 dB for the 39-week-old baby, and at 10 or possibly 5 dB for the 34-week-old baby. Thus, the two methods evoked closely similar physiological responses at the highest and lowest intensities used, and the likelihood that the earphone had collapsed the ear canals can be ruled out.

The measurements in Figure 1 confirm what our earlier paper reported, namely, an absolute threshold estimate made under an earphone in the ICN environment can be close to what one might expect to obtain from an adult ear inside a sound-treated audiologic testing booth. The figure also shows, somewhat surprisingly, that the insert method had no measurable advantage over the earphone procedure at the lowest signal levels at which infant ears respond.

Table 1 assembles all the available data on the 31 ears tested. Figure 2 is a condensed version of Table 1; in it, each insert-earphone difference listed in Table 1 is entered by its amount and the threshold level at which the difference was established. Thus, the two ears of Figure 1 are entered in the upper left corner of Figure 2, where they join four other ears with absolute thresholds between 5 and 20 dB nHL and identical insert and earphone estimates; the bottom entry in the 5–20 column shows that for nine other low-threshold ears the insert estimate was 10 dB better than the earphone estimate.

The column headed 25–35 contains the critical 30 dB nHL stimulus intensity that for some audiologists is a screening pass-fail criterion and for others the suprathreshold index of a normal-hearing threshold. An interesting statistic to be extracted is the number of times the earphone and insert methods agree that a given baby's absolute threshold estimate places him/her below, at, or above the critical 30-dB level. If the 10 ears that can answer this question are

Absolute Threshold Range (dB)

Insert better (dB)	5–20	25–35	40–50	n
0	6	5	3	14
5	0	3	2	5
10	9	2	1	12
	15	10	6	31

Figure 2 Threshold differences from Table 1 condensed.

identified in Table 1, it will be found that the two methods agree at the 25-, 30-, or 35-dB level in all but three instances; in these three cases, the earphone estimate was always 35 dB compared to insert estimates of either 30 dB (two cases) or 25 dB. Thus, 3 ears with thresholds close to the borderline-normal 30 dB by the insert method would have failed with a hearing loss of 5 dB by the earphone method.

The entries in the 40–50 column show six ears with elevated threshold by the insert method; the earphone estimate either agreed with the insert estimate (three ears) or was higher by 5 dB (two ears) or 10 dB (one ear).

DISCUSSION

Collapsed Ear Canals?

There are three possible reasons for the 5- and 10-dB threshold differences in Figure 2. First, during routine testing of ICN infants, an occasional difference of this magnitude in successive threshold estimates by any method would not be considered unusual. However, the random measurement-error explanation is inconsistent with the fact that the insert estimate is always smaller than the corresponding earphone estimate when not equal to it. Among the possible reasons for this asymmetric result are these: an imperfect seal where the earphone meets the pinna, which from time to time allows signal energy to escape and masking noise to enter; and signal attenuation, because the earphone collapses the ear canal and causes an artificial conductive hearing loss. The imperfect seal explanation is consistent with the fact that by far the largest number of insert-earphone differences appear at the lowest threshold intensities, which is where the effects of such leakage artifacts would be noticed most often.

Unfortunately, there is no certain way to decide whether a given insert-earphone difference in Table 1 is due to measurement error, an imperfect seal, or canal collapse. If one assumes canal collapse caused every one of the differences, the loss produced is no more than 5 dB in 61 percent of the measurements and never more than 10 dB in any of them. At the signal level of greatest interest, 30 dB nHL, canal collapse would produce differences of 5 dB (two cases) or 10 dB (once) and change the classification of three babies. As for the claim noted at the beginning of this paper—namely, that canal collapse is responsible for the high prevalence of hearing loss in newborn populations tested under an earphone—Table 1 contains 11 ears with threshold elevations between 35 and 50 dB by *both* insert and earphone; obviously, none of these hearing losses could possibly have been caused by collapsed canals. Finally, nothing in the data helps explain the fact that thresholds of second level babies are elevated half as often as those of third level babies. It would appear, then, that even after the hypothetical worst cases are included in the count, our measurements provide little support for a claim that clinics like ours report large numbers of ICN babies with elevated ABR thresholds because our earphones collapse ear canals (e.g., Hall et al, 1988; Schwartz and Schwartz, 1991).

Opposing Database

The collapsed canal idea was introduced into the literature on the basis of earphone ABRs recorded 3 months apart from a single infant and anecdotal accounts (i.e., no data) involving two additional infants and one adult (Hosford-Dunn, Runge, Hillel, and Johnson, 1983). The only other published evidence known to us comes from two studies by Gorga, Reiland, Beauchaine, Worthington, and Jesteadt (1987) and Gorga, Kaminski, and Beauchaine (1988). The first of these reported a 16 percent failure rate at 30 dB for a group of 699 ICN graduates tested by the earphone method, whereas a second study from the same ICN found thresholds elevated in "approximately 5%" of 177 ears tested by the insert method. The authors state they believe the difference between their 16 percent and approximately 5 percent estimates is due to collapsed ear canals during the earphone measurements. However, in our limited sample, no more than 3 of the 11 earphone failures to respond at 30 dB could possibly be due to collapsed ear canals. Resolving this disagreement will require more measurements in which both methods are used on the same ear in a single session.

Substitute Inserts for Earphones in ICN Testing?

This report shows that healthy ICN graduates can, in the ICN environment, produce ABRs to clicks as weak as 5 or 10 dB nHL delivered through an earphone on the ear; that the absolute threshold estimates made by the insert and earphone methods are often identical; and that when these threshold estimates differ the insert estimate is always lower, but never by more than 10 dB. Listed below are additional aspects of our comparison of the two methods that may be useful to those debating the use of earphones and inserts in newborn hearing testing.

1. The insert seems to be more invasive than the earphone. In our tests, some babies, seemingly annoyed by the tube in the ear, slept less soundly, moved more frequently, and prolonged the session by movement artifacts that required more response averaging.
2. Placing and fixing the insert tube in the ear canal and periodically examining and adjusting its position take more care, time, and effort than merely placing and adjusting an earphone.
3. If both ABR and otoacoustic emissions measurements are to be made on a given subject, using the insert method for both would be most efficient, because the emissions measurement requires the insert.
4. A direct comparison of the two methods on the same subjects will be instructive. In our program, where the goal is to obtain a threshold estimate for each ear, the disadvantages of the insert method clearly outweigh its single advantage, which is an estimate that averages about 5 dB below that of the earphone approximately half the time. Because this small difference approximates the variability of test–retest measurements obtained with either method by itself, we have decided to continue using earphones, even though several authorities strongly advise against this (e.g., Schwartz and Schwartz, 1991; Hall, 1992).

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