Hearing Sensitivity in Newborns Estimated from ABRs to Bone-conducted Sounds

Barbara Cone-Wesson*
Glendy M. Ramirez†

Abstract
This study focused on the problem of estimating hearing sensitivity in newborns from auditory brainstem responses (ABRs) evoked by clicks and 500 Hz and 4000 Hz tonebursts presented by a bone-conduction (BC) oscillator. The effects of acoustic energy transmitted to the ear canal, gender, and ear differences were also investigated. ABR thresholds for BC stimuli were 56, 52, and 53 dB (re 1 μN) or -5, -14, and 0 dB nHL (re adult psychophysical threshold) for click and 500 Hz and 4000 Hz tonebursts, respectively. For newborns, ear canal SPLs generated by the BC stimuli were as much as 21 dB greater than those in adults. Gender-related threshold differences were significant, with female infants having lower thresholds than males; however, ear differences were not. The findings of this study can be used to set appropriate BC stimulus levels for screening or assessment of newborns.

Key Words: Auditory brainstem response, bone conduction, newborn, threshold estimation

Abbreviations: ABR = auditory brainstem response, EAC = external auditory canal, EOAE = evoked otoacoustic emission

Although pure-tone bone-conduction (BC) threshold tests have been part of the standard audiologic test battery for more than 40 years, there are no published data for pure-tone hearing sensitivity in infants using this stimulus delivery method. This limits accurate distinction between conductive, mixed, and sensorineural hearing loss in infants and toddlers. That infant hearing sensitivity for BC stimuli is different from adults is certainly evident from studies in which auditory brainstem responses (ABRs) were used to estimate threshold (Yang et al, 1987; Stapells and Ruben, 1989; Foxe and Stapells, 1993; Stuart et al, 1994). These results show that for both tonal and click BC stimuli, infants have ABR thresholds that are below adult psychophysical threshold, even though infant ABR thresholds for air-conducted (AC) stimuli appear to be elevated with respect to adults (Sininger and Abdala, 1996). These findings confound the ability to make accurate assessments of an air-bone gap or to determine the extent of “cochlear reserve.”

A factor that has spurred interest in BC-ABR tests is the effort to develop cost-efficient hearing screening methods in the newborn period and then accurate audiologic assessment protocols for those infants who fail such screening tests. Early efforts to use ABR (with AC stimuli) for newborn hearing screening revealed a sizable proportion of infants with transient conductive loss. That is, follow-up tests indicated that the hearing loss detected in the newborn period appeared to have resolved within the few weeks or months between initial screening and subsequent assessment (Stein et al, 1983). While some of these conductive losses may have been due to earphone placement resulting in collapsed ear canals (Hosford-Dunn et al, 1983), most newborns have vernix caseosa in the external auditory canal (EAC) (McClellan and Webb, 1957) and in the immediate perinatal period some newborns also have unresolved amniotic fluid and/or mesenchyme in the middle ear space (Eavey, 1993; Roberts et al, 1995). The presence of these materials could cause conductive hearing loss and elevate AC-ABR thresholds. Evidence for elevated AC-ABR thresholds during...
the first 48 hours after birth is provided by Stuart et al (1994). The less than ideal EAC and middle ear status within the first 48 hours after birth also diminishes the applicability of screening methods based upon evoked otoacoustic emissions (EOAEs), since an unoccluded EAC and middle ear are prerequisites for obtaining a response (Kemp et al, 1990). If the goal of the screening program is to detect infants with sensorineural hearing impairments, then use of a BC stimulus may prove to be beneficial and cost effective. Yang et al (1993) demonstrated the feasibility of using BC stimuli for ABR tests in a screening context.

There have been a number of studies that showed that the BC-ABR can enhance the efficacy of audiologic assessment protocols (for review, see Cone-Wesson, 1995). Despite fairly substantial literature about how BC-ABRs may be used in clinical contexts, there have been only a few studies that attempted to define threshold for BC stimuli. Gorga et al (1993) compared ABR thresholds for AC versus BC click and tonal stimuli in adults. They showed that BC-ABR thresholds for low-frequency stimuli were at a higher dB nHL level than for AC stimuli, but in the high frequencies and for clicks there were no significant differences. Stuart et al (1994) compared AC and BC-ABR thresholds (for clicks) obtained from newborn infants and showed that BC-ABR threshold was within 2 dB of adult psychophysical threshold at 0 to 96 hours postpartum, while AC-ABR thresholds decreased from 14 to 4 dB re adult psychophysical threshold during that same period. Foxe and Stapells (1993) estimated ABR threshold for BC tonebursts for nine infants at 500 Hz and for eight infants at 2000 Hz and in a group of normal-hearing young adults (N = 13). They found that the infants had better thresholds than adults for 500 Hz and poorer thresholds than adults at 2000 Hz. There is no consensus regarding what (BC) stimulus levels should be used as a basis for screening or diagnostic testing of neonates or young infants.

Recent studies of newborn ABR threshold for AC clicks and tonebursts revealed gender and ear (Sininger et al, 1996) differences for ABR threshold, amplitude, and latency. ABR thresholds for AC clicks and tonebursts (500–8000 Hz) were better for newborn male infants compared to females, but ABR amplitudes were larger and ABR latencies were shorter for female infants. These latency and amplitude findings were similar to those from studies of adults (Stockard et al, 1978), while the threshold results were somewhat paradoxical. In addition, thresholds were better for the right ear compared to the left ear in male newborns, but for female infants ear differences were found only at 4000 Hz and 8000 Hz, with a left ear threshold advantage. Gender and ear differences have not previously been investigated for BC evoked ABRs.

The goal of the present study was to define ABR threshold for newborn infants for three different stimuli: a click, a 500-Hz toneburst, and a 4000-Hz toneburst. We reasoned that clicks have ubiquitous use in newborn hearing screening with ABR and EOAE tests, so it was important to define BC threshold for this stimulus. A 500-Hz toneburst was used because it is well recognized that conductive hearing loss is most likely to affect low-frequency hearing thresholds, and we wished to provide data that may be used to delineate a low-frequency conductive loss from a sensorineural loss. A 4000-Hz stimulus was used because we wished to provide data useful for assessment of high-frequency sensorineural loss. In addition, we wished to evaluate whether gender or ear differences were apparent in ABR thresholds, latencies, or amplitudes evoked by BC stimuli.

**METHOD**

**Participants**

The participants in this study were newborn infants born at the Los Angeles County-University of Southern California Medical Center, Women and Children’s Hospital. All tests took place prior to hospital discharge, usually on the second day after birth, at 36 to 48 hours. Infants were recruited for study on the basis of their normal birth history, Apgar score greater than 8 at 1 and 5 minutes, no evident risk factors for hearing impairment (JCIH, 1991), and normal newborn examination, performed by the nurse-practitioner or physician assistants. Parental consent was obtained for all procedures.

The participants were recruited for this investigation of BC-ABR threshold in conjunction with a larger study of newborn hearing screening methods (Identification of Neonatal Hearing Impairment, R10-DC-0958). As part of the larger study, each infant had an ABR hearing screening test with AC clicks presented at 30 dB nHL (64 dB peSPL), a transient-evoked otoacoustic emission test with clicks presented at 80 dB SPL, and a distortion product otoacoustic emissions test with primary tones presented at levels of 65 and 50 dB SPL for F1 and F2, respectively, and an F2/F1 frequency ratio.
Infants were included in the current study of ABR threshold for BC stimuli when ABRs were present and when EOAEs were present with a signal-to-noise ratio of at least 3 dB at 1.5 kHz and 6 dB at 2 kHz to 4 kHz. These rigorous criteria ensured that the participants in the BC-ABR threshold investigation had a normal auditory periphery as indicated by AC-ABR and EOAE tests.

Seventy-seven newborns were tested but the data reported are from 60 of those participants, 33 males and 27 females. Data were excluded on the basis of being incomplete, that is, when a threshold search had been initiated but not completed due to test-time constraints. Each threshold determination took approximately 20 minutes and always followed the EOAE and AC-ABR tests. Four infants had two threshold tests in one test session; otherwise, only one threshold determination was made per infant. We obtained 20 thresholds each for clicks and at 4000 Hz and 24 thresholds at 500 Hz, for a total of 64 threshold determinations.

**Stimuli**

The clicks were 100-μsec square-wave pulses. The 500-Hz toneburst had a 2-msec rise/fall time and an 2-msec plateau, while the 4000-Hz toneburst had a 1-msec rise/fall time and a 1-msec plateau; both were ramped with a Blackman window. The toneburst stimuli were embedded in one-octave notched noise at a signal-to-noise level of 20 dB. All stimuli were digitally constructed and output with a Neuroscan “Stim” system and were presented at 25/sec via a Radio Ear B70 oscillator.

**Calibration**

Levels (in dB re 1 μN) for click and toneburst stimuli were determined in the following manner. For toneburst stimuli, pure tones with the same nominal frequency (500 and 4000 Hz) were used as reference and, for the click, a 1-kHz pure tone was used. The peak-to-peak voltage and force level of a pure tone (V<sub>p</sub>) was measured from the output of a BC oscillator (Radio Ear B70) coupled to an artificial mastoid (Bruel and Kjaer Model #3505) and level meter (Bruel and Kjaer Model #2209). (The oscillator was coupled to the artificial mastoid with 400 grams of force). Then the peak-to-peak voltage of the transient (V<sub>t</sub>) was measured from the display of an oscilloscope. Using the formula 20 log V<sub>t</sub>/V<sub>p</sub>, the “peak-to-peak equivalent” dB level (p-peSPL) of the transient relative to the pure tone was determined.

Eight female adults with normal hearing were tested to determine hearing thresholds for the test stimuli. Standard psychophysical techniques were used. In addition, three adults underwent ABR threshold tests to serve as reference points against which newborn data could be compared.

The SPLs of BC stimuli were measured in the ear canal for two adults and three newborns. Tubing from a probe-microphone assembly (Etymotic ER-7) was inserted into the ear canal, approximately 4 mm in the newborns and 8 mm in the adults. The BC oscillator was positioned as for an ABR test. SPLs were recorded for each of the test stimuli, presented at 90 to 110 dB re 1 μN.

**ABR Recording Parameters**

ABRs were recorded from either a vertex (C<sub>z</sub>) to nape-of-neck (C<sub>7</sub>) montage or a vertex to mastoid (M<sub>3</sub>) montage, over a 40-msec time window and a .03 to 1 kHz bandpass filter with a slope of 12 dB per octave, and a 10-kHz sampling rate, using a Neuroscan “Scan” data acquisition system. Each response was averaged until background noise level, measured with a single point estimate (Don and Elberling, 1996), was less than 30 nV, or when a maximum of 6000 samples were obtained. Samples were rejected when voltages exceeded ±20 μV and, on average, 4352 sweeps were averaged per trial.

**Procedures**

Infants were swaddled and placed in a lateral-supine position in an isolette custom designed for newborn hearing tests (Eckels ABC-100 Infant Acoustic Isolette). The BC oscillator was placed superior and anterior to the mastoid bone in the position recommended by Stuart et al (1990) and was adjusted to a coupling force of 400 ± 25 grams, using a spring scale in the manner described by Yang and Stuart (1990) and a custom-made elastic headband fastened with self-adherent fabric closures (Velcro). A bracketing procedure using a 5-dB step size was used to determine threshold.

**Analyses**

ABRs were judged by two experienced observers. Threshold was interpolated as the level midway between a response clearly present
in the recording and at a level showing no response. ABR wave V latency was measured at the most positive point of the waveform, and amplitudes were measured from that peak to the succeeding trough at the most negative point. Analyses of variance were used to evaluate threshold, latency, and amplitude differences as a function of gender, ear, and stimulus, with a p < .05 significance level.

**RESULTS**

**Threshold**

Figure 1 shows representative waveforms for each of the stimuli, recorded with presentation levels that were above and below the infant's ABR threshold. Wave V is apparent in all recordings down to threshold level, but earlier ABR components, waves I and III, are usually not, and may be obscured by the transducer artifact at high stimulus levels.

ABR thresholds for BC stimuli in newborns were 56, 52, and 53 dB (re 1 μN) for click and 500- and 4000-Hz tonebursts, respectively. An analysis of variance for threshold differences as a function of stimulus type was not significant (F = 1.35, df = 2,6 1, p > .05). A two-factor analysis of variance for threshold differences as a function of gender and ear revealed a significant effect for gender (F = 7.082, df = 1,45, p < .05) but not for ear (F = .450, df = 1,45, p > .05) or for a gender vs ear interaction. Figure 2 shows the mean thresholds with the standard deviation for male and female newborns as a function of stimulus type and indicates that female newborns have lower thresholds compared to male newborns.

The mean hearing and ABR thresholds for adults are plotted with the mean newborn BC-ABR thresholds in Figure 3. When newborn

![Figure 1](image1.png)  
**Figure 1** Examples of ABRs evoked by BC click and 500-Hz and 4000-Hz toneburst. Stimulus levels indicated are dB p-pSPL re 1 μN. Placement of the BC oscillator in the superior-anterior position (relative to the mastoid bone) and recording from a Cz-C3 montage reduces stimulus artifact.

![Figure 2](image2.png)  
**Figure 2** Female and male ABR thresholds for BC stimuli.

![Figure 3](image3.png)  
**Figure 3** Psychophysical and ABR thresholds for adults and ABR thresholds for infants for three different stimuli.
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22.00-
20.00-
18.00-
16.00-
14.00-
12.00-
10.00-
8.00-
6.00-
4.00-
2.00-

Figure 4 A, ABR latencies as a function of level for BC stimuli; B, ABR amplitudes as a function of level for BC stimuli.

BC-ABR thresholds are referenced to the adult hearing thresholds, the levels are -5, -14, and 0 dB nHL for click and 500- and 4000-Hz stimuli.

Latency

Figure 4A shows ABR latency as a function of level for each of the three stimuli. As expected, latencies for the 500-Hz toneburst are prolonged relative to those for a click or 4000-Hz toneburst. The slope of the regression line for 500 Hz is slightly steeper compared to those for clicks and 4000 Hz. There is considerable variability in latency measures as they were made for responses recorded near threshold. There were no significant differences in latency attributable to gender or ear differences at these low levels of stimulation.

Amplitude

Figure 4B shows ABR amplitude as a function of level for each of the three stimuli. The click stimuli at suprathreshold levels evoked ABRs of larger amplitude compared to the toneburst stimuli, but all amplitudes tend to converge near threshold, as amplitude is the way in which ABR threshold is defined. The amplitude growth function for clicks is steeper than the growth functions for 500- or 4000-Hz responses. For these amplitude measures made at levels close to threshold, there were no significant differences in amplitude attributable to gender or ear differences.

Ear Canal SPL

The SPLs of the BC stimuli measured in the ear canal of adults were compared to those measured in three newborns, and the infant-adult level differences are plotted in Figure 5. At 500 Hz, the newborns had SPLs that were 5 to 21 dB greater than those in adults at 4000 Hz and for clicks the range was 4 to 22 dB.

DISCUSSION

The results of this investigation establish BC-ABR thresholds for newborns for three different stimuli, and these empirically determined levels can be used in hearing screening.
Table 1  Psychophysical (PSY) and BC-ABR Thresholds (re 1 μN) from the Current Literature

<table>
<thead>
<tr>
<th>Article</th>
<th>Test Population</th>
<th>Click</th>
<th>500 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kramer 1992</td>
<td>Adult females</td>
<td>53.4</td>
<td>69.2</td>
<td>51</td>
<td>PSY</td>
<td></td>
</tr>
<tr>
<td>Foxe and Stapells, 1993</td>
<td>Adults</td>
<td>74</td>
<td>50</td>
<td>PSY</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adults</td>
<td>78 ± 10</td>
<td>58 ± 8</td>
<td>ABR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Infants</td>
<td>77 ± 10</td>
<td>63 ± 7</td>
<td>ABR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gorga et al, 1993</td>
<td>Adults</td>
<td>51.5</td>
<td>72.2</td>
<td>48.1</td>
<td>40.2</td>
<td>PSY</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>61.0</td>
<td>97.7</td>
<td>63.1</td>
<td>48</td>
<td>ABR</td>
</tr>
<tr>
<td>Stuart et al, 1994</td>
<td>Newborns</td>
<td>56.8 ± 4.9</td>
<td>74</td>
<td>50</td>
<td>ABR</td>
<td></td>
</tr>
<tr>
<td>Stapells and Ruben, 1989</td>
<td>Adults</td>
<td>74</td>
<td>50</td>
<td>PSY*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Infants</td>
<td>84</td>
<td>60</td>
<td>ABR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cone-Wesson and Ramirez, 1997</td>
<td>Adults</td>
<td>61</td>
<td>66</td>
<td>53</td>
<td>PSY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Newborns</td>
<td>56</td>
<td>52</td>
<td>53</td>
<td>ABR</td>
<td></td>
</tr>
<tr>
<td>ANSI, 1992 (pure tones)</td>
<td>Adults</td>
<td>42.5**</td>
<td>58</td>
<td>31</td>
<td>35.5</td>
<td>PSY</td>
</tr>
</tbody>
</table>

*Thresholds estimated from point on histogram at which 50% of normal infants had responses; **1 kHz used as reference for clicks.

and clinical assessment. ABR thresholds for BC stimuli in newborn infants appear to be close to or better than adult psychophysical threshold for brief stimuli. Table 1 summarizes BC threshold data obtained in this and other studies that had infant or adult participants. The click thresholds obtained in the present study are identical to those of Stuart et al (1994). Newborn ABRs are obtained at click levels within 5 dB of adult psychophysical threshold and at a level of 56 dB re 1 μN. For 500 Hz, the results are not consistent across studies. Infant ABR thresholds for 500 Hz range from 5 to 84 dB re 1 μN, and in adults the range is 78 to 97.7 dB re μN. The newborn ABR thresholds for 4 kHz in this study are close to the ABR thresholds for adults established by Gorga et al (1993).

Newborn vs Adult Differences in ABR Thresholds

Other investigators (Yang et al, 1987; Stuart et al, 1990; Foxe and Stapells, 1993) have written elegantly about the way in which the skull characteristics may differ in young infants compared to adults, resulting in a "louder" stimulus at the cochlea and hence lower thresholds, shorter latencies, and larger amplitudes. Summarizing their discussions, the temporal bone area over which the oscillator is placed is smaller relative to the adult and the temporal bone sutures have not ossified in the newborn period. This could result in greater effectiveness of the force levels driving the temporal bone, with less dispersion of vibratory energy to the rest of the skull. In this study, we measured an additional factor that could account for the "improved" thresholds in newborns, that of ear canal SPL for BC stimuli. When the BC transducer is coupled to the skull, there is greater transmission of acoustic energy (up to 22 dB) to the EAC in newborns compared to adults. The acoustic energy, generated by the BC stimuli and measured in the EAC, suggests that the osseotympanic mode of BC transmission (Dirks, 1973) may be 4 to 22 dB greater for the newborn compared to adults. Both otoacoustic admittance (Holte et al, 1991) and acoustic reflectance (Keefe et al, 1993) reveal significant differences between infant and adult tympanic membrane and middle ear characteristics, which reduce sound transmission (particularly for high frequencies) through the tympanic membrane-middle ear system. The apparent "transparency" of the neonatal EAC for acoustic energy created by the BC stimulus is likely, however, to be a factor in the discrepancy between neonatal and adult BC-ABR thresholds. The infant-adult differences in BC transmission demonstrated in this and other studies indicate that the use of an adult psychophysical threshold reference for infant BC-ABRs may not be meaningful.

The discrepancy between infant and adult ABR thresholds for AC stimuli has been demonstrated by Sininger et al (1997). Their results show that when newborn ABR thresholds are expressed with respect to a coupler calibration, differences between adult and infant ABR
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threshold are underestimated. In their study, the SPLs of the AC toneburst stimuli were measured within the ear canal, close to the tympanic membrane for both newborn and adult subjects. When ABR thresholds were expressed in dB SPL at the eardrum, then there were differences in threshold between infant and adult, with infants having 3 dB poorer thresholds for 500 Hz, 14 dB poorer for 4000 Hz, and 15 dB poorer for clicks. Another remarkable finding was that newborn ABR thresholds varied by less than 4 dB in the frequency range 500 to 8000 Hz, whereas in adults the difference between the best threshold (4000 Hz) and the poorest threshold (500 Hz) was 22 dB. We have replicated many of the procedures of Sininger et al. (1997), including the stimulus waveforms, ABR threshold detection procedures, ABR acquisition parameters, and measurement of stimulus levels in the ear canal, in order to facilitate comparison of the two data sets. If adult psychophysical thresholds are used as a reference for infant ABR thresholds, then the infant ABRs appear to be better than or at adult psychophysical threshold. If the differences in BC stimulus level in the EAC are considered additive (to the infant BC-ABR threshold), then the infant BC-ABR thresholds are 2 dB poorer at 500 Hz, 15 dB poorer for 4000 Hz, and 4 dB poorer for clicks than adult psychophysical threshold for these BC stimuli. The findings for BC tonebursts are remarkably similar to those for AC stimuli. The discrepancy between the findings for the click stimulus may be due to the poor transduction properties of both the BC oscillator and the infant skull for the high-frequency spectral components of clicks.

Gender and Ear Differences in ABR Threshold

The issues of gender and ear differences in auditory function have received intensive study in adults, with gender differences particularly apparent with increasing age (Pearson et al., 1995) and ear differences (related to cortical specialization) apparent for more complex stimuli, such as speech or music (Kimura, 1967). There is very little information regarding gender and ear differences in early infancy or childhood. Adult females have larger ABR amplitudes and shorter latencies compared to adult males (Stockhard et al., 1978), and the latency differences are present even in the newborn period (Chiarenza et al., 1988; Eldridge and Salamy, 1996). The shorter latencies and higher amplitudes are thought to be due to shorter cochlear length in females compared to males (Don et al., 1993), but whether the underlying differences in cochlear anatomy would lead to better thresholds in females is not clear. The Sininger et al. (1996) study showed better ABR thresholds for male newborns, but the current findings with BC stimuli show better ABR thresholds for female newborns. Considering the results of Sininger et al. (1996) and the current findings, there appears to be a greater air-bone gap for female infants. As noted previously, all newborns had normal EOAEs, a control for middle ear status, but there may be gender-related differences in bone density or maturation of the skull sutures that would affect transmission of the BC signal to the cochlea. Furthermore, an interactive effect of skull asymmetry and (electrode) recording montage could affect the determination of gender-related (or ear-related) threshold differences. We have yet to determine if, at birth, there are gender-related differences in cochlear length and innervation density contributing to sensitivity, or whether there are gender-related differences in auditory nerve and brainstem pathway maturity in newborns that could affect ABR threshold, and, finally, whether and how maternal hormones influence the newborn's auditory nervous system.

Ear differences for sensitivity have received little attention in the literature, even though the brain has definite structural and functional asymmetries (Witelson and Pallie, 1973; Geschwind, 1979). While the Sininger et al. (1996) study found ear asymmetries in sensitivity for both male and female infants, the present study did not. There have been no anatomic studies of right ear vs left ear differences for either the conductive or sensorineural mechanism that could help account for ear asymmetries in sensitivity. The finding that spontaneous OAEs are more prevalent in right than left ears, even in newborns (Burns et al., 1992), suggests that such anatomic asymmetries exist. The effect of such anatomic or functional differences on ABR threshold estimates is unknown.

BC-ABRs for Screening and Assessment

An ABR screening test or assessment with a BC stimulus may be most appropriate if EOAE tests show no response, which may be due to middle ear and EAC transmission factors, rather than cochlear dysfunction. All newborns in our study had EOAEs for the frequency range
encompassing the click and 4000-Hz toneburst stimuli. The EOAEs indicate that the external ear and middle ear were free of any debris that would alter the conductive mechanism. ABRs for AC stimuli at low level were also evident, another indication that the participants in this study would have near normal (for age) conductive mechanism. We do not claim, however, that the BC-ABR thresholds represent absolute cochlear reserve, as it is well known that middle ear mass and stiffness may alter BC thresholds. Testing infants with robust EOAEs and ABRs, however, precludes any additional conductive factors influencing the results of the threshold tests. We recommend BC stimulus levels for screening tests no more than 30 dB above threshold levels established by this study, in order to detect those newborns with mild impairment. For assessment protocols, the threshold data from this study may be used to gauge an estimate of hearing loss in both the low- and high-frequency range. We now plan to extend the findings by replicating this study of BC thresholds in 6- to 8-month-old infants, with confirmation of the threshold estimates from ABR by determining psychophysical thresholds obtained in an operant conditioning test paradigm.

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