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Neonatal Auditory Brainstem Response Thresholds To Air- and Bone-Conducted Clicks: 0 to 96 Hours Postpartum

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Abstract

Auditory brainstem response (ABR) thresholds to air- and bone-conducted clicks were investigated in 40 full-term neonates. Subjects were divided into two groups of 20 according to postpartum age: less than 48 hours and between 49 and 96 hours. Mean ABR thresholds to air- and bone-conducted clicks for neonates less than 48 hours postpartum were 14.5 dB nHL (51.5 dB peak SPL) and 1.8 dB nHL (36.8 peak re: 1 μN), respectively, while those for neonates between 49 and 96 hours were 3.8 dB nHL (40.8 dB peak SPL) and 1.5 dB nHL (36.5 dB peak re: 1 μN), respectively. A significant difference was found between the two group mean ABR thresholds to air-conducted stimuli ($p < .0001$) but not for the bone-conducted stimuli ($p < .8959$). A statistically significant within-group difference was found between the ABR thresholds to air- and bone-conducted stimuli for only the neonates less than 48 hours of age ($p < .0001$). When the data was collapsed across groups, simple linear regression analyses revealed a statistically significant relation between postpartum age and ABR threshold to air-conducted stimuli ($p < .0001$) and a nonsignificant relation between postpartum age and ABR threshold to bone-conducted stimuli ($p < .9744$). These findings support the notion that some resolution of fluids and residuals in the middle ear occurs during the first 48 hours postpartum and that air-conducted stimuli are attenuated during that period. As such, a physiologic conductive deficit among the younger neonates is suggested.

Key Words: Air- and bone-conducted clicks, auditory brainstem response (ABR), child, hearing disorders, neonate, threshold

The auditory brainstem response (ABR), an objective tool for the assessment of the peripheral auditory status (Hecox and Galambos, 1974), has been advocated for the audiologic screening of newborn infants (Schulman-Galambos and Galambos, 1979; Alberti et al, 1983; Stein et al, 1983; Galambos et al, 1984; Jacobson and Morehouse, 1984; Durieux-Smith et al, 1985b). It has been recognized that the initial failure rate of 11 to 41 percent for at-risk infants far exceeds the 2 to 4 percent incidence of severe-to-profound hearing losses among this population (see Hall et al, 1988 for a review). However, 3- to 12-month follow-up evaluations have typically revealed ABR abnormalities in 2 to 5 percent of infants tested. In an effort to avoid high initial failure rates during the newborn period, it has been suggested that one should postpone initial testing until 3 to 5 months corrected age (Hyde et al, 1984; Durieux-Smith et al, 1987) or use a higher screening level (Stein et al, 1983).

Transient middle ear disorders have received considerable attention as one of the, if not the primary, contributors to these initial ABR screening failures. Numerous studies have documented that the newborn's middle ear cavity contains various materials and is not fully pneumatized at birth. For example, histopathologic studies of neonatal temporal bones with necroscopy have demonstrated the presence of embryonic connective tissue (Buch and Jørgensen, 1964a; McLellan et al, 1964),

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debris and/or residuals (e.g., mesenchyme and cellular components; Buch and Jørgensen, 1964a; McLellan et al, 1964; Proctor, 1964; deSa, 1973; Paparella et al, 1980), aspirated amniotic fluid (Benner, 1940; Buch and Jørgensen, 1964b; deSa, 1973), and both serous and suppurative exudate (McLellan et al, 1962, 1964; Buch and Jørgenson 1964b; deSa, 1973; Paparella et al, 1980). Clinical studies have also reported the presence of exudate (McLellan et al, 1967; Jaffe et al, 1970; Warren and Stool, 1971; Shurin et al, 1976; Balkany et al, 1978; Berman et al, 1978). Further, the presence of vernix caseosa has been documented universally in the external auditory canal of full-term neonates (McLellan and Webb, 1957, 1961; Balkany et al, 1978), although is seldom seen in the premature infant (McLellan and Struck, 1965).

Seminal studies investigating neonatal middle ear function questioned the notion of materials central to the tympanic membrane at birth as normal tympanometric findings were seen as early as a few hours following birth (Keith, 1973, 1975). The findings of Paradise et al (1978), however, questioned the diagnostic value of these findings in that young infants may present with normal tympanograms in the presence of middle ear effusion due to the distensibility of the external auditory canal wall. Himelfarb et al (1979) were the first to suggest that the interaction between static resistance and reactance needs to be considered for an accurate interpretation of the patterns observed with neonates. The authors reported "the value of reactance at 220 Hz is usually smaller than resistance. In addition, reactance often assumes a positive sign indicating that the reactance of the ear is often mass dominated" (p. 189). This pattern was not evident in 3- to 4-month-old or adult subjects. These neonatal findings were replicated by Sprague et al (1985), with the authors offering the caution: "Whether this low-frequency resonance reflects the acoustic immittance of the neonatal ear canal instead of the neonatal middle ear is not known. At this time, the two cannot be distinguished because the neonatal ear canal cannot be approximated as a hard walled cavity to allow for the calculation of acoustic immittance at the plane of the tympanic membrane" (p. 270). In a subsequent study, Holte et al (1991) presented data to support the contention that it was unlikely that the unusual tympanometric patterns observed in the neonate were due to the distensibility of the external auditory canal wall but were rather due to middle ear characteristics. They also suggested that "material other than air in the middle ear cavity may add mass to the ossicular chain" (p. 20), dictating a mass controlled system. These later findings appear consistent with the studies that demonstrate that the newborn's middle ear cavity contains various materials and may not be fully pneumatized at birth.

Neonate and infant ABR thresholds to air-conducted click stimuli have been reported by several authors (Schulman-Galambos and Galambos, 1979; Kaga and Tanaka, 1980; Cornacchia et al, 1983; Mochizuki et al, 1983; Lary et al, 1985; Lasky and Yang, 1986; Lasky et al, 1987; Adelman et al, 1990; Sasama, 1990; Stockard and Curran, 1990). Relative to adult ABR thresholds to click stimuli, infant thresholds have been generally reported to be elevated and to converge with age. The transient threshold elevation of the neonatal ABR to air-conducted stimuli has been attributed to middle ear residuals and/or fluid attenuating air-conducted signals to the cochlea (Lasky et al, 1987; Adelman et al, 1990; Stockard and Curran, 1990).

Recently, Stuart et al (1993) reported data contrary to the previous trend of elevated ABR thresholds to air-conducted clicks among neonates relative to adults. Identical mean ABR thresholds of 3.75 dB nHL (40.75 dB peak SPL) were found between 20 full-term neonates, tested between 48 and 72 hours postpartum, and 20 normal-hearing young adults. The authors suggested that a number of test paradigm disparities between this and earlier studies may have contributed to the dissimilar findings. At any rate, the authors questioned the notion that air-conducted stimuli are attenuated by fluid and residuals in the middle ear cavity before reaching the cochlea. The authors did offer a caveat in suggesting that middle ear dynamics may play a role in infants less than 2 days of age postpartum and "that resolution of fluids and residuals is greatest in the first 50 hours following birth and that neonatal ABR thresholds to air conducted stimuli may approximate those of adults after that time" (p. 181). Support for this speculation can be based on the following: their subjects were tested 48 to 72 hours postpartum; ABR thresholds to air-conducted stimuli have been reported to improve in the first 2 days following birth (Lasky et al, 1987; Adelman et al, 1990); postnatal age at testing has seldom been reported (see Adelman et al, 1990), therefore, it is conceivable that test results reflect elevated thresholds in the first 2 days postpartum; and that evoked otoacoustic emissions have been reported to get stronger among neonates tested at least 1 day older following an initial test between 3 and 51 hours of age postpartum (Kok et al, 1992).

Based on previous studies, it was speculated that if the resolution of fluids and residuals in the middle ear occurs prior to 48 hours postpartum, neonates who are assessed during this time should exhibit poorer hearing sensitivity than neonates who are assessed after 48 hours postpartum (i.e., one would predict that subjects tested less than 48 hours postpartum should display higher ABR thresholds to air-conducted clicks than older subjects). If differences are in fact evident between the groups, then one must support the notion that air-conducted stimuli are attenuated by fluid and/or residuals in the middle ear cavity in the first 48 hours postpartum. If similarities are evident between the groups, then one can question the same notion. Further, there is no reason to suspect changes in neonatal cochlear reserve in healthy full-term neonates in the first few days postpartum. As such, one would not expect to find group differences between ABR thresholds to bone-conducted clicks, recognizing that the ABR to bone-conducted stimuli is a feasible method to assess the cochlear reserve in neonates (Hooks and Weber, 1984; Stapells, 1989; Stapells and Ruben, 1989; Yang and Stuart, 1990; Nousak and Stapells, 1992; Yang et al, 1993a). The purpose of this study was, therefore, to investigate the above speculation by comparing ABR thresholds to air- and bone-conducted clicks among neonates less than 48 hours and those greater than 48 hours postpartum.

METHOD

Subjects

Forty full-term newborn infants served as subjects. All subjects met the following criteria: gestational age between 38 and 42 weeks; Apgar scores greater than or equal to 8 at 1 and 5 minutes; birth weight greater than or equal to 2500 g; physically and neurologically normal as judged by neonatal pediatric house staff; free from risk of hearing loss (Joint Committee on Infant Hearing, 1990); and vaginal delivery. Subjects were divided into two groups according to postpartum age at the time of testing. Group 1 consisted of 20 subjects less than 48 hours postpartum (M = 23.6 hours, SD = 10.5, range: 7 to 44 hours; gestational age: M = 39.8, SD = 1.1), while Group 2 consisted of 20 subjects between 49 and 96 hours postpartum (M = 69.4 hours, SD = 10.6, range: 56 to 95 hours; gestational age: M = 39.6, SD = 1.0). All subjects were tested in natural sleep typically following feeding.

Apparatus

All subjects were tested in a quiet room at the Grace Maternity Hospital, Halifax, Nova Scotia. Background noise assessed with a precision sound level meter (Brüel & Kjaer model 2209) with a free-field condenser microphone (Brüel & Kjaer model 4145) was found to be approximately 44 dBA. Each subject was tested using a Nicolet Compact Four evoked potential system.

ABRs were obtained with click stimuli generated by 100 μs rectangular voltage pulses applied to an insert earphone (Nicolet model TIP-300) and a bone vibrator (Radioear model B70-B). The insert earphone was coupled to an impedance tip adapter (Nicolet model 123-717900) with an infant ear tip (Nicolet model 842-507300). The click stimuli were presented at a rate of 57.7 per second with alternating polarity.

Stimulus intensities were calibrated relative to the behavioral thresholds of 13 normal-hearing young adults (M = 23.3 years, SD = 1.7) who were assessed to have 10 dB HL (ANSI, 1989) or better pure-tone thresholds at octave intervals from 250 to 8000 Hz. The behavioral thresholds were determined with clicks of 100 μs rectangular voltage pulse, alternating initial phase, and presented at a rate of 10 per second. The dissimilarity between the stimulus presentation rates for psychophysical threshold determination and electrophysiologic data collection reflected an effort to reduce temporal summation effects (Stapells et al, 1982) in the former and to increase test efficiency (Picton et al, 1983) in the latter. The reference level (0 dB nHL) for the air-conducted click was 37 dB peak sound pressure as measured in a 2-cm^3 acoustic coupler (Brüel & Kjaer model DB-1038) employing a precision sound level meter (Brüel & Kjaer model 2209) with a pressure condenser microphone (Brüel & Kjaer model 4144). The reference level (0 dB nHL) for the bone-conducted click was 35 dB peak re: 1 μN, as measured by the same sound level meter with an artificial mastoid (Brüel & Kjaer model 4930). Signal and spectral analyses for both air- and bone-conducted clicks can be found elsewhere (Stuart et al, 1990; Yang and Stuart, 1990).

Procedures

ABRs to monaural air- and bone-conducted clicks were acquired with stimulation to the left ear of all subjects. The presentation of air- and bone-conducted stimuli was counterbalanced between subjects. For ABRs to air-conducted clicks, the impedance tip adapter with infant ear tip was placed at the entrance to the infants' external auditory meatus. The bone vibrator was placed in a supero-posterior auricular position for bone-conducted stimulus delivery (Yang et al, 1987, 1991, 1993a; Stuart et al, 1990, 1993; Yang and Stuart, 1990; Stuart and Yang, in press). An elastic band (2.5 x 40 cm) with Velcro (attached on the opposite sides of the two ends) was used to hold the bone vibrator in place. Vibrator-to-head coupling force was adjusted to 425 ± 25 g. The coupling force was measured with a hand-held spring scale (Ohaus model 8014) attached to a fine nylon line that was coupled to the bone vibrator. Coupling force was measured at the point the vibrator cleared and became flush with scalp as the vibrator was manually pulled from the head. The spring scale was removed during the ABR recording.

Gold-plated cup electrodes consisting of one (noninverting) attached to the high forehead (Fz); one (inverting) attached to the left inferior postauricular area (M_1); and one (common) attached to the right inferior postauricular area (M_2) were employed. Interelectrode impedances were maintained below 5000 Ω. The recorded electroencephalogram was amplified 10^5 and analogue bandpass filtered (30 to 3000 Hz, Butterworth filter with a roll-off slope of 12 dB/octave). Electroencephalogram samples exceeding ± 25 μV were rejected automatically. An analysis time of 15 msec post-stimulus was sampled at 33 kHz.

ABRs to the air- and bone-conducted clicks were acquired with a starting intensity of 30 dB nHL. Stimulus intensity was decreased in 10-dB steps until an identifiable and replicable wave V peak was no longer attainable. A total of 2048 samples were averaged and replicated for each trial. Stimulus intensity was then increased by 5 dB until a replicable wave V was identifiable. Multiple trials were typically obtained at intensities just above and below threshold. All recordings were stored on floppy diskettes for later analyses.

Presence of the ABR required the agreement of two audiologists experienced in ABR testing. Both observers, who were blind to test condition, inspected the waveforms jointly. The lowest stimulus intensity level for air- and bone-conducted stimulus at which a wave V was identifiable and replicable was considered to be the ABR threshold. Replication was defined as two or more wave forms with identifiable wave V peaks within 0.15 msec. ABR waveforms were also analyzed for wave V latency and amplitude. If the wave V component was trough-like, round, or bimodal, the last point before rapid negative reflection was identified as the peak (Durieux-Smith et al, 1985a). Wave V amplitude was measured from the wave V peak to the most negative following trough within 3 msec before positive deflection (Durieux-Smith et al, 1985a).

RESULTS

Means, standard deviations, and ranges of the ABR thresholds to air- and bone-conducted clicks for both groups of subjects are presented in Table 1. Representative ABR waveforms, from one neonate from each group, to air- and bone-conducted stimuli are displayed in Figures 1 and 2. Figures 3 and 4 display ABR wave V latencies as a function of air- and bone-conducted stimuli from identified and replicated responses in both neonate groups. Table 2 presents means, standard deviations, and ranges of the ABR wave V latencies and amplitudes to air- and bone-conducted clicks at 30 dB nHL.

Between-group (i.e., neonates less than 48 hours of age versus neonates between 49 and 96

Table 1 Means, Standard Deviations, and Ranges of ABR Thresholds to Air- and Bone-Conducted Clicks for Both Neonate Groups

	Postpartum Age (Hours)	
	0–48	*49–96*
Air Conduction dB nHL (dB peak SPL)		
M	14.5 (51.5)	3.8 (40.8)
SD	7.8	4.6
Range	5 to 30	–5 to 10
Bone Conduction dB nHL (dB peak re: 1μN)		
M	1.8 (36.8)	1.5 (36.5)
SD	4.9	6.9
Range	–5 to 15	–10 to 10

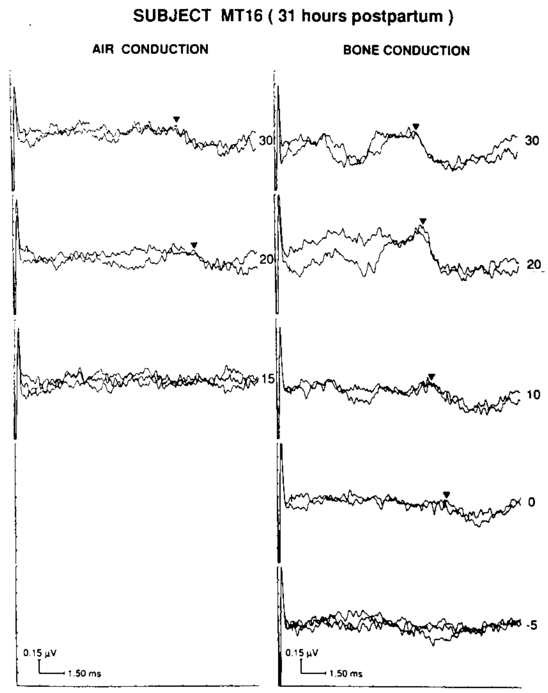

Figure 1 Representative ABR waveforms to air- and bone-conducted clicks from one neonate in Group 1 (less than 48 hours postpartum age) as a function of stimulus intensity level (dB nHL). Filled, inverted triangles denote wave V peaks.

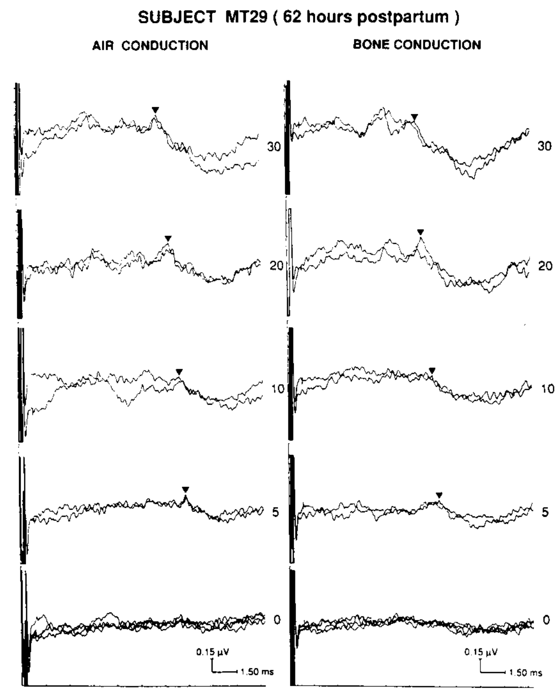

Figure 2 Representative ABR waveforms to air- and bone-conducted clicks from one neonate in Group 2 (49 to 96 hours postpartum age) as a function of stimulus intensity level (dB nHL). Filled, inverted triangles denote wave V peaks.

Table 2 Means, Standard Deviations, and Ranges of ABR Wave V Latencies (Msec) and Amplitudes (µV) to Air- and Bone-Conducted Clicks at 30 dB nHL for Both Neonate Groups

	Postpartum Age (Hours)	
	0–48	*49–96*
Air Conduction		
Latency		
M	8.84	8.56
SD	0.58	0.53
Range	8.01–9.90	7.74–9.69
Amplitude		
M	0.31	0.40
SD	0.10	0.14
Range	0.13–0.47	0.21–0.68
Bone Conduction		
Latency		
M	8.41	8.37
SD	0.44	0.54
Range	7.62–9.42	7.56–9.54
Amplitude		
M	0.37	0.42
SD	0.12	0.11
Range	0.14–0.61	0.27–0.67

hours of age) threshold differences for air- and bone-conducted stimuli were investigated with separate t tests for unpaired samples. A significant difference was observed between thresholds for air-conducted stimuli ($t[38] = 5.342$, $p = .0001$) but not for bone-conducted stimuli ($t[38] = .1317$, $p = .8959$).

Mean ABR threshold differences between air- and bone-conducted stimulus conditions for both groups of neonates were investigated with separate t tests for paired samples. A statistically significant difference was found between mean ABR thresholds to air- and bone-conducted stimuli for neonates less than 48 hours of age ($t[19] = 6.168$, $p = .0001$). For the neonates between 49 and 96 hours of age, a nonsignificant difference between mean ABR thresholds to air- and bone-conducted stimuli was found ($t[19] = 1.406$, $p = .176$).

Separate t tests for unpaired samples were also utilized to compare ABR wave V latency and amplitude differences to air- and bone-conducted stimuli between groups. Adopting an α level of .01 to correct for multiple between-group comparisons, it was found that mean

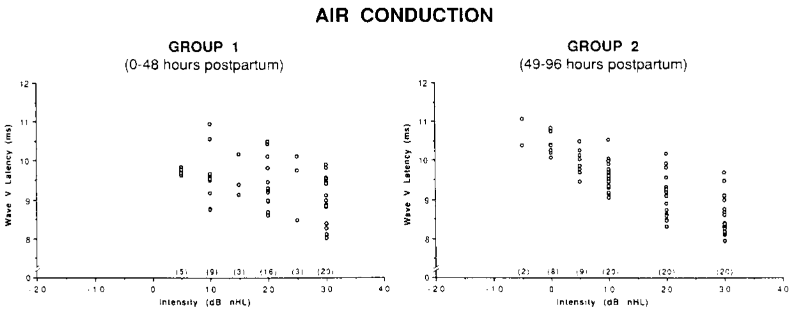

Figure 3 ABR wave V latencies from identifiable and replicable waveforms as a function of stimulus intensity level (dB nHL) to air-conducted clicks in both neonate groups. Numbers in parentheses represent total number of data points for identifiable and replicable responses per stimulus intensity level.

wave V latencies (t [38] = 1.620, p = .1134) and amplitudes (t [38] = –2.580, p = .0139) for air-conducted stimuli were not statistically significant.[1] Likewise, nonsignificant group differences were found for wave V latencies (t [38] = .2204, p = .8267) and amplitudes for bone-conducted stimuli (t [38] = –1.656, p = .106).

To further examine the relationship between postpartum age and ABR thresholds to air- and bone-conducted clicks, the data were collapsed across groups for correlation and regression analyses. A significant negative correlation was found between postpartum age and ABR threshold to air-conducted stimuli (r = –.610, p < .0001). A nonsignificant correlation was found between postpartum age and ABR threshold to bone-conducted stimuli (r = –.005, p = .9745). Simple linear regression analyses revealed a statistically significant relation between postpartum age and ABR threshold to air-conducted stimuli (F [1,38] = 22.54, p < .0001) and a nonsignificant relation between postpartum age and ABR threshold to bone-conducted stimuli (F [1,38] = .001, p = .9744). That is, knowledge of postpartum age will enhance the prediction of ABR thresholds to air-conducted stimuli but not that of ABR thresholds to bone-conducted stimuli. The bivariate regression plots of these data are presented in Figures 5 and 6.

[1]It has been suggested that when the test statistic falls between the uncorrected α critical value (i.e., .05) and the critical familywise α, one should "suspend judgement" concerning the status of the null hypothesis (Keppel, 1982; Keppel and Zedeck, 1989). That is, one "recognizes the ambiguity that exists when a comparison is significant under one criterion but not significant under a more severe criterion. By suspending judgement, we avoid committing either type of error, and simply conclude the evidence is not sufficiently strong to justify either one of the usual conclusions. Since we have not rejected the null hypothesis, no type I error is committed, and the familywise error is left unaffected by this decision. Since we have suspended judgement, no type II error is committed, and interesting and unexpected findings. . .can be assimilated into the interpretation of the experiment and perhaps earmarked for future replication and study" (Keppel, 1982, p. 164).

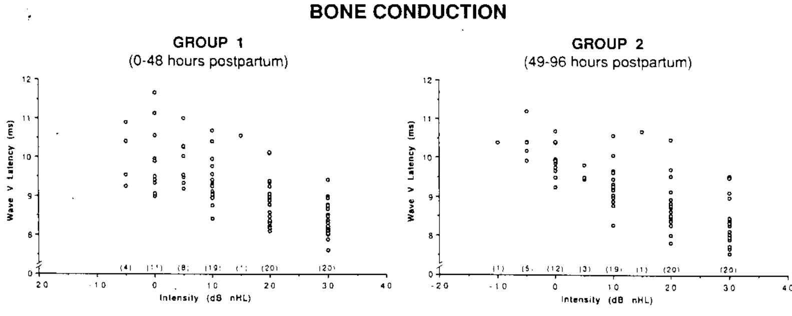

Figure 4 ABR wave V latencies from identifiable and replicable waveforms as a function of stimulus intensity level (dB nHL) to bone-conducted clicks in both neonate groups. Numbers in parentheses represent total number of data points for identifiable and replicable responses per stimulus intensity level.

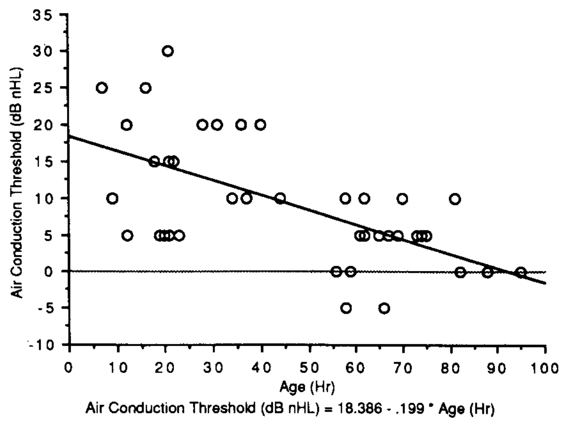

Figure 5 Bivariate regression plot for air-conduction thresholds and postpartum age.

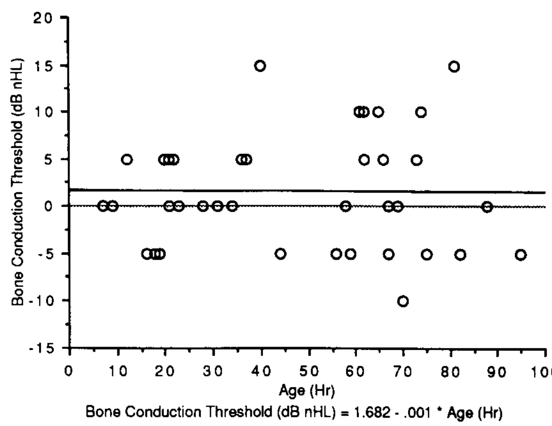

Figure 6 Bivariate regression plot for bone-conduction threshold and postpartum age.

DISCUSSION

The findings from the present study suggest that auditory sensitivity, as reflected in mean ABR thresholds to air-conducted clicks, differs between neonates less than 48 hours postpartum age and those between 49 and 96 hours postpartum age. This does not suggest, however, that the cochlear reserve of these infants is dissimilar, as differences between mean ABR thresholds to bone-conducted clicks were not found to be statistically significant. Divergent patterns were evident in the relationship of within-group differences between ABR thresholds to air- and bone-conducted clicks (i.e., and air-bone gap). A statistically significant difference was found between the ABR thresholds to air- and bone-conducted stimuli for the neonates less than 48 hours of age as opposed to a statistically nonsignificant difference with the neonates between 49 and 96 hours of age. This would suggest physiologic conductive deficit among the younger neonates (Yang et al, 1987, 1993a; Yang and Stuart, 1990). These findings support the notion that some resolution of fluids and residuals in the middle ear occurs during the first 48 hours postpartum and that air-conducted stimuli are attenuated during that period. As well, there is no evidence to suggest that the cochlear reserve of apparently healthy, full-term neonates changes in the first 4 days postpartum. Further, statistical analyses suggest that knowledge of postpartum age enhances the prediction of ABR thresholds to air-conducted stimuli but not that of ABR thresholds to bone-conducted stimuli. Considering the above, we would concur with the Kok et al (1992) suggestion that the audiologic screening of newborns should not be undertaken shortly after birth (i.e., less than 48 hours postpartum).

The present findings, although contradictory to previous findings documenting elevated ABR thresholds to air-conducted clicks relative to adults (Schulman-Galambos and Galambos, 1979; Kaga and Tanaka, 1980; Cornacchia et al, 1983; Mochizuki et al, 1983; Lary et al, 1985; Lasky and Yang, 1986; Lasky et al, 1987; Adelman et al, 1990; Sasama, 1990; Stockard and Curran, 1990), replicate those of Stuart et al (1993). That is, comparable ABR thresholds to air-conducted clicks were reported among neonates older than 48 hours postpartum in this study as were reported among those neonates aged 48 to 72 hours and the adult subjects in the previous study. As well, ABR thresholds to bone-conducted clicks were essentially the same between the three neonate groups: 1.8, 1.5 dB nHL and 1.25 dB nHL for the 0- to 48- and 49- to 96-hour-old subjects from this study and the 48- to 72-hour-old subjects from Stuart et al (1993), respectively. Although the absolute values of ABR thresholds to air-conducted stimuli may not be comparable due to test paradigm disparities, these findings are similar to those that document a reduction in ABR thresholds in the first days postpartum (Lasky et al, 1987; Adelman et al, 1990).

The findings of the present study again raise the question: when does the middle ear clear following birth? These results suggest that changes are occurring within the first 2 days postpartum. Results from the above mentioned ABR (Lasky et al, 1987; Adelman et al, 1990) and otoacoustic emission studies (Kok et al, 1992) are consistent with this speculation. That is not to say, however, that all neonates in the first day(s) postpartum will universally present with elevated ABR thresholds to air-conducted stimuli. As evident in the present data, there was considerable variability in ABR thresholds to air-conducted stimuli among neonates less than 48 hours of age, and some subjects presented with thresholds as low as 5 dB nHL. This should not be surprising, considering that although the majority of middle ears reported in anatomical and clinical studies were not clear, there were a number that were (McLellan et al, 1962, 1967; Buch and Jørgensen, 1964b; Jaffe et al, 1970; Warren and Stool, 1971; deSa, 1973; Balkany et al, 1978; Paparella et al, 1980). As well, it may be the case that resolution of vernix caseosa in the external auditory meatus contributes to an improvement in the ABR threshold to air-conducted stimuli. Although it has been reported to be a universal occurrence in the ears of full-term neonates less than 24 hours postpartum and spontaneously clear by 4 to 6 days, it has never been reported to completely obstruct the external auditory meatus (McLellan and Webb, 1957, 1961; Balkany et al, 1978). As such, the contribution to a physiologic conductive deficit among neonates less than 48 hours postpartum may be considered minimal, if not nonexistent. The role of vernix caseosa in affecting premature infants' hearing sensitivity can be considered negligible (McLellan and Struck, 1965). Finally, this study does not necessarily suggest that the middle ears of neonates are completely resolved of fluids and residuals by 48 hours postpartum. In fact, the middle ear may continue to clear following this period. As Adelman et al (1990) have demonstrated, ABR thresholds to air-conducted stimuli continue to improve during the 2-week period following birth.

A logical extension of the above raised question, then, is how does the middle ear clear? A current theory towards the physiology of the eustachian tube and middle ear dictates that the three following components exist in cooperation and continual interplay in the pressure regulation process: diffusion of gas (liberation and absorption), exchange of fluid (elimination and production), and tubal passage of fluids and gasses (up and down) (Magnuson and Falk, 1988). It could be postulated that, in order for the middle ear to be pneumatized, there needs to be either liberation of gasses in the middle ear, elimination of fluid (either through absorption in the middle ear or passage down the eustachian tube), and/or aeration of the middle ear with passage up the eustachian tube. There appears to be evidence for at least the latter two phenomena. It is well recognized that when the tensor veli palatini contracts during swallowing, it opens the eustachian tube, allowing for an ingress of air into the middle ear cavity (Crelin, 1973). Further, ciliated respiratory epithelium that line the eustachian tube and continue into the middle ear "stream" towards the nasopharynx, allowing for the passage of fluid and residuals from the middle ear (Crelin, 1973; Wong, 1983). One could also speculate that the negative intraoral pressure developed during sucking may facilitate drawing fluid from the middle ear. Finally, as is generally recognized that passage through the birth canal facilitates normal drainage of fluid from the lungs, some have speculated that the same may influence passage of fluids from the middle ear down the eustachian tube (Buch and Jørgensen, 1964a).

With respect to latency and amplitude measures, the ABR results for air- and bone-conducted clicks at 30 dB nHL found with the neonates between 49 and 96 hours of age and the ABR results to bone-conducted clicks from the neonates less than 48 hours postpartum are comparable with previous results from subjects tested under identical conditions (Yang et al, 1987, 1991, 1993a, b; Stuart et al, 1990, 1993; Yang and Stuart, 1990; Stuart and Yang, in press). Although the ABR results from the younger neonates to air-conducted clicks did not attain statistical significance, a trend of wave V latencies to be longer and wave V amplitudes to be smaller than those of the older neonates is consistent with the notion that the air-conducted signal is attenuated by residuals and/or fluid in the middle ear cavity.

In conclusion, the results of the present study suggest a dissimilarity between ABR thresholds to air-conducted clicks but not between bone-conducted clicks among neonates less than 48 and those between 49 and 96 hours of age postpartum. As well, a statistically significant difference between the ABR thresholds to air- and bone-conducted stimuli for the neonates less than 48 hours of age as opposed to a statistically nonsignificant difference with the neonates greater than 48 hours of age suggests a physiologic conductive deficit among the younger neonates. These findings support the notion that some resolution of fluids and residuals in the middle ear occurs during the first 48 hours postpartum and that air-conducted stimuli are attenuated during that period.

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