The Contribution of the Auditory Brainstem Responses to Bone-Conducted Stimuli in Newborn Hearing Screening

Contribution des potentiels évoqués auditifs par conduction osseuse pour le dépistage de la surdité chez les nouveau-nés

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Abstract

Both the auditory brainstem response (ABR) to air-conducted stimuli and evoked otoacoustic emissions have been questioned for their lack of specificity for permanent sensorineural hearing loss during the newborn period. Unfortunately, prevailing indices for detecting middle ear dysfunction such as otoscopy and tympanometry have not demonstrated adequate success to serve as a second line of screening during this time. The use of ABR to bone-conducted stimuli during the newborn period to differentiate sensorineural from conductive auditory deficits and thereby improving the efficiency of screening methods is advocated herein. Specifically a two-staged approach for the universal hearing screening of newborns prior to hospital discharge is suggested. The utilization of the ABR to air-conducted tonal stimuli (i.e., 500 and 2000 Hz) as a first line of testing is offered. Infants who display an identifiable and replicable ABR wave V to 30 dB nHL air-conducted tonal stimuli with a latency within plus two standard deviations of the mean of the age appropriate normative data in both ears are considered a "pass." For those infants that "fail" the initial hearing screening test, the employment of bone-conducted tonal stimuli is recommended. The purpose of this article is to summarize procedures associated with the implementation of ABR to bone-conducted stimuli with controlled signal delivery in the audiological screening/assessment of young infants.

Abrégé

La spécificités des potentiels évoqués auditifs par conduction aérienne tout autant que celle des oto-émissions acoustiques a été mise en doute à cause de leur imprécision quant à la surdité permanente de perception chez les nouveau-nés. Malheureusement, les indices prédominants pour dépister des troubles de l'oreille moyenne, telles que l'otoscopie et la tympanométrie, n'ont pas fait leurs preuves comme deuxième moyen de dépistage. Le présent article vante les mérites du recours aux potentiels évoqués auditifs par conduction osseuse chez les enfants en très bas âge pour différencier les pertes neuro-sensorielles des pertes de transmission. Plus précisément, il préconise une approche en deux volets pour le dépistage universel de la surdité chez les nouveau-nés avant le congés de l'hôpital. L'utilisation des potentiels évoqués auditifs en réponse à une tonalité aérienne (p. ex. : 500 et 2 000 Hz) comme premier moyen de dépistage est offerte. On considère que les poupons « réussissent » lorsqu'ils affichent une onde V distincte et répétée en réaction à un stimulus par tonalité aérienne de 30 dB nHL avec une latence ne dépassant pas deux écarts-types pour la moyenne d'âge appropriée, et ce, dans les deux oreilles. Pour les enfants qui « échouent » au test de dépistage initial, on recommande le recours à des stimuli par conduction osseuse. Cet article fait un tour d'horizon des procédures liées à l'application des potentiels évoqués auditifs en réponse à des stimuli par conduction osseuse avec transmission du signal contrôlée lors du dépistage et de l'évaluation audiologique des jeunes enfants.

Key words: ABR to bone-conducted stimuli, newborn hearing screening

It is generally accepted that the purpose of any screening protocol is to identify those individuals who have a greater probability of having a disease or pathology in order that they may be referred for further diagnostic evaluation (American Speech-Language-Hearing Association, 1995, 1997; Jacobson, 1990). Further, the choice of a screening test should be based on its ease of administration, comfort to the individual, cost effectiveness, and be short in duration. In addition, the test must demonstrate satisfactory test operating characteristics (i.e., be sensitive and specific). Both the purpose and choice of a newborn hearing screening protocol is identifying hearing impairment at birth in order to facilitate the necessary habilitation in a timely manner. To achieve this goal, current models recommend the screening of all newborns (American Speech-Language-Hearing Association, 1997; National Institute of Health, 1993). Both the auditory brainstem response (ABR) and otoacoustic emissions (OAEs) have been recommended (American Speech-Language-Hearing Association, 1997; National Institute of Health, 1993) and instituted for screening for hearing impairment (e.g., Bonfils, Dumont, Marie, Francois & Narcy, 1990; Durieux-Smith, Picton, Bernard, MacMurray, & Goodman, 1991; Galambos, Hicks, & Wilson, 1984; Gravel et al., 2000; Jacobson & Morehouse, 1984; Johnson, Maxon, White, & Vohr, 1993; Kemp & Ryan, 1993; Norton, 1994; Spivak et al., 2000; Stein, Özdamar, Kraus, & Paton, 1983).

The diagnostic criteria for hearing impairment that universal hearing screening programs identify vary, however. For example, in its Consensus Statement, the National Institute of Health (1993) recommended screening for moderate, severe, and profound hearing impairment. On the other hand, the American Speech-Language-Hearing Association (1997) defined hearing impairment as unilateral or bilateral sensorineural and/or conductive hearing losses greater than 20 dB HL but concedes that current screening methods allow only for the reliable detection of impairments of 30 dB HL or greater. Traditionally, programs have attempted to identify permanent sensorineural hearing loss of a degree that impedes normal speech and language development (Jacobson, 1990; Joint Committee on Infant Hearing, 1994).

Both the ABR to air-conducted stimuli and OAEs have been questioned on their lack of specificity (i.e., high false positive rates) for *permanent sensorineural hearing loss* during the newborn period (Kemp, Ryan & Bray, 1990; Maxon, White, Vohr, & Behrens, 1993; Norton & Widen, 1990; Stockard & Curran, 1990; Vohr, White, Maxon, & Johnson1993). Many have argued, at least for the ABR, that screening results adequately reflect *hearing status* but do not predict transient auditory or neurologic pathology (Durieux-Smith et al., 1991; Jacobson & Morehouse, 1984;Jacobson & Jacobson, 1987).

Conductive hearing loss as a result of transient middle ear dysfunction has been implicated as a principal cause of initial hearing screening failures to air-conducted stimuli. Support for this notion has come from both experimental and clinical data: Numerous studies have documented that the middle ear cavity of a newborn contains various materials and is not fully pneumatized at birth. For example, histopathological studies of neonatal temporal bones with necroscopy have demonstrated the presence of embryonic connective tissue (Buch & Jørgensen, 1964a; McLellan, Brown, Rondeau, Shoughro, Johnson, & Hale, 1964), debris and/or residuals (e.g., mesenchyme and cellular components; Buch & Jørgensen, 1964a; deSa, 1973; McLellan et al., 1964; Paparella, Shea, Meyerhoff, & Goycoolea, 1980; Proctor, 1964), aspirated amniotic fluid (Benner, 1940; Buch & Jørgensen, 1964b; deSa), and both serous and suppurative exudate (Buch & Jørgensen 1964b; deSa; McLellan et al., 1964; McLellan, Strong, Johnson, & Dent, 1962; Paparella et al.). Clinical studies have also reported the presence of exudate (Balkany, Berman, Simmons, & Jafek, 1978; Berman, Balkany, & Simmons, 1978; Jaffe, Hurtado, & Hurtado, 1970; McLellan, Strong, Vautier, & Blatt, 1967; Shurin, Pelton, &, Klein, 1976; Warren & Stool, 1971).

Unfortunately, prevailing indices for detecting middle ear dysfunction have not demonstrated adequate success to serve as a second line of screening during the newborn period. That is, otoscopy is difficult (Berman, et al., 1978; Groothius, 1982; Schreiner & Kiesling, 1981) and tympanometry employing a low-frequency probe tone is unreliable (Himelfarb, Popelka, & Shanon, 1979; Holte, Margolis, & Cavanaugh, 1991; Paradise, Smith, & Bluestone, 1976; Schwartz & Schwartz, 1978; Sprague, Wiley, & Goldstein, 1985). Higher probe tone frequency tympanometry (McKinley, Grose, & Roush, 1997) and wide band reflectance measures (Keefe, Bulen, Arehart, & Burns, 1993; Keefe & Levi, 1996) may prove to be more effective. What remains is the challenge to improve the specificity of screening methods employing air-conducted stimuli. In other words, how does one distinguish between ABR abnormalities due to permanent sensorineural hearing loss and conductive pathology as a consequence of transient middle ear dysfunction during the newborn period?

Bone-conducted stimulus delivery in conjunction with air-conducted stimulus delivery, a third means employed to differentiate sensorineural and conducted pathologies has been under-implemented in the clinical assessment of newborn hearing status. This practice stands in the face of more than 20 years of accumulated research that has demonstrated that ABR to bone-conducted stimuli is a viable test measure (Cone-Wesson, 1995; Cone-Wesson & Ramirez, 1997; Cornacchia, Martini & Morra, 1983; Foxe & Stapells, 1993; Gorga, Kaminski, Beauchaine & Bergman, 1993; Hicks, 1980; Hooks & Weber, 1984; Muchnik, Neeman & Hildesheimer 1995; Nousak & Stapells, 1992; Stapells, 1989; Stapells, & Oates, 1997; Stapells & Ruben, 1989; Stuart & Yang, 1994; Stuart, Yang & Stenstrom, 1990; Stuart, Yang, Stenstrom & Reindorp, 1993; Tucci, Ruth & Lambert, 1990; Warren, 1989; Weber, 1983; Yang, Rupert, & Moushegian, 1987; Yang & Stuart, 1990; Yang, Stuart, Mencher, Mencher, & Vincer;1993; Yang, Stuart, Stenstrom & Green, 1993;Yang, Stuart, Stenstrom & Hollett, 1991; Ysunza & Cone-Wesson, 1987). The use of ABR to bone-conducted stimuli during the newborn period has been advocated for differentiating sensorineural from conductive auditory deficits and thereby improving the efficiency of screening methods (Hooks & Weber, 1984, Stapells & Ruben, 1989; Yang, et al., 1987; 1993). That is, this procedure is recommended for testing neonates and very young infants who fail to pass a hearing screening with either ABR to air-conducted stimuli or evoked OAEs. To effectively obtain consistent and reliable test results utilizing the ABR to bone-conducted stimuli, however, attention must be given to a number of factors. One must be cognizant of underlying anatomical differences between newborns and adults and pay particular attention to controlled signal delivery. The purpose of this article is to summarize procedures associated with the implementation of ABR to bone-conducted stimuli with controlled signal delivery in the audiological screening/assessment of young infants.

Anatomical Differences in Cranial Structure Between Neonates And Adults

The newborn and adult crania differ vastly. An understanding of these differences facilitates an appreciation for the need for controlled bone-conducted stimulus delivery during the newborn period. To begin with, the temporal bone articulates with four other cranial bones, that is, the occipital, parietal, sphenoid, and zygomatic. In the adult, as well as older infants and children, these bones are tightly serrated (Bast & Anson, 1949) and bone-conducted vibratory stimuli drive the cranium as a whole. This is not the case with the neonatal cranium. Membranous sutures separate the temporal bone of neonates from surrounding cranial bones (Crelin, 1973; Pierce, Maimen, & Bosma, 1978). Further, at gestational term the temporal bone consists of three unfused components namely the petrosal, squamosal, and annulus (Pierce et al.). Whereby the petrosal and squamosal communicate by bony approximation along the petro-squamosal suture (Pierce et al.) the squamosal and petrosal articulate with the parietal and occipital bones by the membranous squamo-parietal and petro-occipital sutures, respectively (Anson, Bast, & Richard, 1955; Bast & Anson, 1949; Crelin). The mastoid is formed at birth but the mastoid process is essentially devoid. The relative size of the newborn temporal bone is approximately one-half to one-third that of an adult. Housed in the petrosal are the membranous and bony labyrinths of the cochlea. The two labyrinths are adult size at birth (Crelin; Wong, 1983). As the petrosal is basically adult size and does not develop significantly post-parturitionaly, the cochlea occupies a relatively larger area of the temporal bone in the neonate than the adult does (Crelin; Wong).

It has been suggested that the effective intensity of a bone-conducted signal, if delivered from a posterior auricular bone vibrator placement, is greater in neonates than in adults (Foxe & Stapells, 1993; Stuart et al., 1990; Stuart, Yang & Green, 1994). In a posterior placement the bone vibrator rests medial to the auricle adjacent to its attachment to the skull such that the inferior longitudinal margin of the bone vibrator is parallel to a horizontal line drawn from the center of the entrance to the external auditory meatus. The posterior placement is believed to deliver more effective stimulus output to the petrosal area of the temporal bone. As the placement of the bone vibrator moves from the posterior through a superoposterior to a superior position effective stimulus delivery decreases as vibratory energy is disseminated through surrounding membranous sutures resulting in an attenuated signal reaching the cochlea. Placement of the bone vibrator on other cranial bones (e.g., frontal or occipital bones) results in further attenuation of vibratory energy (Yang et al., 1987). For this reason, it has been estimated that the interaural attenuation of a bone-conducted click is approximately 25 to 35 dB for the neonate and 15 to 25 dB for the one-year old infant (Yang et al.). In clinical testing of ABRs to bone-conducted stimuli with one year olds, masking of the contralateral ear is recommended. When evaluating neonates, masking of the non-test ear may be required at higher stimulus levels, for example, at 35 dB nHL (Yang et al.). Hence, the masking of non-test ear is of less concern when testing neonates with bone-conducted stimulation.

Delivery of Bone-Conducted Stimuli

Click generated by 100 μs rectangular voltage pulses and delivered through a bone vibrator (Radioear B70B) can be used to evoke ABR (Yang et al, 1987). Click stimuli presented at a fast rate such as 57.7/s with alternating polarity are recommended. For screening purposes stimulus intensity level of 30 dB nHL may be used (Yang et al., 1993). Unmasked click evoked ABRs have been, however, criticized for not being able to provide accurate information about hearing sensitivity at specific frequencies because of the broad band nature of the stimulus (Hall, 1992; Hyde, 1985; Stapells, 1989, 1994). That is, ABRs to unmasked clicks tend to underestimate the degree of impairment or in fact fail to detect hearing losses.

For frequency specific stimulation, Stapells and colleagues (Foxe & Stapells, 1993; Nousak & Stapells, 1992; Stapells, 1989; Stapells & Oates, 1997; Stapells & Ruben, 1989) have suggested the use of bone-conducted tonal stimuli for the assessment of newborns and young infants. ABRs to bone-conducted tonal stimuli show good frequency and place specificity particularly at low stimulus levels (Kramer, 1992; Nousak & Stapells). Linearly gated tones with 2-1-2 rise-plateau-fall cycles with alternating onset polarity are recommended. Presentation rate should be between 37 and 41/s. Reliable ABRs to unmasked tonal stimuli of 20 and 30 dB nHL can be recorded at 500 Hz and 2000 Hz, respectively in infants (Foxe & Stapells; Nousak & Stapells; Stapells; Stapells & Ruben).

For controlled bone-conducted stimulus delivery, a fine nylon line is attached under the single casing screw head at the distal end of the vibrator and then looped and tied around the transducer cord adjacent to the proximal end of the vibrator. An elastic band with Velcro attached to the opposite ends is used to hold the vibrator in place. The elastic band is adjusted to maintain a vibrator-to-head coupling force of 425 ± 25 g. The elastic band was then positioned around the infant's head under the loop of nylon fishing line and against the bone vibrator. A spring scale (e.g., Ohaus Model 8014; available at most scientific supply companies) is attached to the fishing line and the vibrator is then manually pulled away from the scalp; coupling force is measured at the point when the vibrator clears and becomes flush with the scalp (Yang & Stuart, 1990).

Recording Paradigm

For screening applications at lower stimulus levels an ipsilateral (i.e., noninverting electrode located at the vertex or high forehead with the inverting electrode located on the stimulus-ipsilateral earlobe or mastoid) or vertical montage (i.e., noninverting electrode located at the vertex or high forehead with the inverting electrode located on nape of the neck) is recommended (Stuart, Yang, & Botea, 1994). Yang, Stuart, and colleagues have employed the ipsilateral montage, consisting of three gold-plated cup electrodes including one attached to the high forehead (F_z), one attached to the inferior ipsilateral postauricular area (M_i), and one (common) attached to the inferior contralateral postauricular (M_c), for ease of electrode application. Interelectrode impedance should be maintained below 5000 Ω. Artifact reject is recommended to set to ± 25 µV. A total of 2048 samples are typically averaged and replicated for each stimulus condition. Analyses times of 15 and 25 ms are suitable for recording ABRs to click and tonal stimuli, respectively stimulus (Stapells & Oates, 1997; Yang & Stuart, 1990).

The recorded electroencephalogram should be amplified 10^5 times and bandpass filtered (30 to 3000 Hz). Less restrictive high-pass filtering (e.g., 30 Hz) is recommended. Neonatal ABR to bone-conducted clicks are systematically affected by changes in high-pass analog filtering. That is, statistically significant reductions in wave V amplitude and decreases in wave V latency are observed for at low level stimulus intensities with a progressive increase in the high-pass filter cutoff (Stuart & Yang, 1994). The most pronounced effect is a statistically significant reduction in wave V amplitude. Compared to a 30 Hz high-pass filter cutoff, 40 to 50% reductions in wave V are experienced with high-pass cutoff frequencies of 100 and 150 Hz respectively for bone-conducted stimuli. The consequence of increasing the high-pass filter is a pronounced loss of the "slow" component of the ABR, which contributes largely to the spectral content of wave V (Kavanagh, Domico, Franks, & Jin-Cheng, 1988; Laukli & Mair, 1981).

Essential Considerations in Bone-Conducted Signal Delivery

First and foremost, one needs to recognize that ABR wave V latencies are affected by bone vibrator placements about the skull (e.g., frontal vs. occipital vs. temporal bone placements; Yang et al., 1987). Changes in bone vibrator placement influence effective stimulus delivery to the cochlea. Furthermore, ABR wave V latencies are affected by bone vibrator placements around the temporal area (i.e., superior vs. supero-posterior vs. posterior placements; Stuart et al., 1990). It is paramount that the bone vibrator placement remains consistent when implementing the ABR to bone-conducted stimuli in neonates and young infants. A supero-posterior temporal area placement is recommended in testing neonates (Stuart et al., 1990) for practical purposes.

A second considerations in bone-conducted signal delivery, is the appreciation that ABR wave V latencies to bone-conducted stimulus have been demonstrated to be significantly affected when the vibrator to head coupling force exceeds 225 ± 25 g (Yang et al., 1991). That is, as vibrator to head coupling force increases from 225 ± 25 g to 525 ± 25 g wave V latency significantly decreases. When the coupling force is 225 ± 25 g there is a greater susceptibility that the vibrator is displaced with head movement by the neonate during testing. On the other hand, when the coupling force is 525 ± 25 g there is a higher propensity that the elastic band holding the bone vibrator in place will slide off the infant's head. For these reasons it is suggested that a coupling force of approximately 400 ± 25 g be implemented. At the very least it is essential that vibrator to head coupling force be controlled and remain consistent when implementing the ABR to bone-conducted stimuli in infants. The practice of holding the vibrator by hand is discouraged. It is suggest that such a method is susceptible to lack of constant vibrator-to-head coupling force and possible stimulus damping (see for example Wilber, 1979). In addition, the use of leather bands or double-sided adhesive tape (e.g., Hooks & Weber, 1984) is likewise not supported. Although vibrator placement may be controlled, means to verify vibrator to head coupling force with these techniques are not readily available.

Interpretation of Test Results

In the analyses of results of ABR to bone-conducted click stimuli, an abnormal finding is defined when the ABR elicited at 30 dB nHL does not show an identifiable and replicable wave V with a latency within plus two standard deviations of the mean of the age appropriate normative data (Yang et al., 1993). Examples of age appropriate reference values are displayed in Table 1. The degrees of auditory deficits during the newborn period have been classified as mild-to-moderate or severe-to-profound. Mild-to-moderate deficits are defined in ears which exhibited an identifiable and replicable ABR wave V at 30, 45, or 60 dB nHL with a latency exceeding normal limits or an identifiable and replicable ABR wave V at 45 and/or 60 dB nHL but not at 30 dB nHL (i.e., the ABR threshold was equal to or better than 60 dB nHL). Severe-to-profound deficits are defined in ears which an ABR wave V at 60 dB nHL cannot be identified (i.e., the ABR threshold was worse than 60 dB nHL). Furthermore, based on the contrast of ABR findings between air and bone-conducted stimuli (i.e., air-bone gap), the types of auditory deficits are classified as sensorineural, conductive, or mixed. Ears that exhibited severe-to-profound deficits with no detectable ABR to bone conducted stimuli at the output limitation of the bone vibrator (approximately 45 to 50 dB nHL) are classified as severe-to-profound sensorineural deficits. It is recognized, however, that due to the limited dynamic range of the bone conducted click stimuli, a conductive component cannot be ruled out in these cases.

Table 1. Mean ABR Wave V Latency (ms), Standard Deviation, and Upper Limit (i.e., Mean Plus Two Standard Deviations) to Bone-Conducted Clicks at 30 dB nHL Presented at a Rate of 57.7/s as a Function of Age Level.

Age Level	Mean	Standard Deviation	Upper Limit
Neonate	8.67	0.43	9.53
Four Month	7.76	0.33	8.42
One Year	7.44	0.23	7.92
Adult	7.50	0.38	8.26

Although ABRs to bone-conducted tonal stimuli have shown a good correspondence between normal cochlear sensitivity in infants with a diversity of external and middle ear pathologies (e.g., Gravel, Kurtzberg, Stapells, Vaughan, & Wallace, 1989; Picton, Durieux-Smith, & Moran, 1994; Stapells & Ruben, 1989) there has yet to be a definitive study on how well ABR test results correspond to behavioural thresholds to bone-conducted tonal stimuli. Toward that realization, there remains no definitive suggestion as to how to interpret ABR test results to bone-conducted tonal stimuli during the newborn period.

Newborn Versus Adult Differences in ABRs To Bone-Conducted Stimuli

Wave V latencies of ABRs to air-conducted click stimuli have been reported to be shorter than from bone conducted stimuli at comparable stimulus intensity levels (Mauldin & Jerger, 1979; Weber, 1983; Yang et al., 1987). With newborn infants Wave V latencies have been reported to be similar with air- and bone-conducted click stimuli at comparable stimulus intensity levels (Stuart et al., 1990, 1993; 1994; Yang et al., 1987; 1991). It is possible, however, that by manipulating controlled signal deliver either through changes in coupling force or bone vibrator placement the effective stimulus intensity delivered to the cochlea may be changed (Stuart et al., 1990; Yang et al., 1987, 1991). That being the case, the relationship of wave V latencies to air- and bone-conducted stimuli may be revealed to be shorter, longer, or equivalent in neonates.

Newborn ABR thresholds to bone-conducted clicks appear to be better than adults' ABR thresholds if adult psychophysical thresholds are used as a reference (Cone-Wesson & Ramirez, 1997; Foxe & Stapells, 1993; Nousak & Stapells, 1992; Stuart et al., 1994). Infants display better thresholds to 500 Hz bone-conducted tonal stimuli than adults but the reverse is true for 2000 Hz bone-conducted tonal stimuli (Foxe & Stapells; Stapells & Ruben, 1989). There is a high correlation between ABR threshold estimates and pure-tone thresholds for bone-conducted signals. ABR measures to bone-conducted clicks and tonal stimuli tend, however, to underestimate pure tone thresholds (Cone-Wesson, 1995; Stapells & Ruben).

Clinical Implications for Newborn Hearing Screening and Conclusions

The ABR to bone-conducted stimuli has proven to be a feasible and reliable means for the identification of congenital sensorineural deficits in newborns (Cone-Wesson & Ramirez, 1997; Hooks & Weber, 1984; Nousak & Stapells, 1992; Stapells & Ruben, 1989; Yang & Stuart, 1990; Yang et al., 1993). When one attends to stimulus delivery control reliable results can be expected (Yang, Stuart, Stenstrom, & Green, 1993). It is suggested that the ABR to bone-conducted stimuli be viewed as a valuable addition in the assessment of cochlear reserve in infants who fail newborn auditory screening to air-conducted stimuli.

Specifically, a two-staged approach is recommended for the universal hearing screening of newborns prior to hospital discharge. The use of the ABR to air-conducted tonal stimuli (i.e., 500 and 2000 Hz) is suggested as a first line of testing. Infants who display an identifiable and replicable ABR wave V to 30 dB nHL air-conducted tonal stimuli with a latency within plus two standard deviations of the mean of the age appropriate normative data in both ears are considered a "pass". These infants may be discharged from the screening program if they do not exhibit any risk factor for hearing impairment. For those infants who fail the initial hearing screening test to air-conducted stimuli, the employment of bone-conducted tonal stimuli is advocated (i.e., 500 and 2000 Hz) as a means of preventing first line failures from encumbering follow-up testing diagnostic evaluation. That is, neonates who fail the initial hearing need be rescreened by ABR to bone-conducted tonal stimuli in an effort to differentiate permanent sensorineural hearing loss from conductive pathology as a consequence of transient middle ear dysfunction prior to hospital discharge. Infants who fail the second line of ABR screening with bone-conducted tonal stimuli need be referred for a diagnostic evaluation. Implementation of the follow-up diagnostic evaluation is necessary to verify the existence of and to determine the severity of any hearing impairment in an effort to initiate any habilitative program for the infant. Ideally those referred from screening should receive diagnostic confirmation of auditory status within one month but not later than three months of discharge (American Speech-Language-Hearing Association, 1997). For those infants who fail the initial hearing screening test to air-conducted stimuli but pass the second line of ABR screening with bone-conducted tonal stimuli a rescreen with an ABR test to air-conducted tonal stimuli within one month but not later than three months of discharge is recommended. An abnormal finding at the second hearing screening would necessitate a referral for a diagnostic evaluation.

Advantages of utilizing ABR to bone-conducted stimuli are self-evident. First, it allows clinicians to differentiating sensorineural from conductive deficits in neonates who fail an ABR screening using air-conducted stimuli. Second, the timing of identification of substantial sensorineural deficits can be advanced to the earliest stage of life. Finally, immediately following the assessment with ABR to bone-conducted stimuli, it may be psychologically less stressful for parents to be provided with more audiological information than to wait for follow-up testing months later.

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