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Early Hearing Detection andIntervention: Diagnostic Hearing Assessment Practices

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Title: Early Hearing Detection and Intervention: Diagnostic Hearing Assessment Practices

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Abbreviations:

Early Hearing Detection and Intervention (EHDI)
Joint Committee on Infant Hearing (JCIH)
Newborn Hearing Screening (NHS)
Auditory Brainstem Response (ABR)
Operating Room (OR)

ABSTRACT

Purpose: The purpose of this study was to gain an understanding of practice patterns for infant diagnostic hearing services at pediatric audiology facilities.

Method: This study used a cross-sectional survey design. From August to November of 2009 surveys were mailed to 1091 facilities in 28 states and the District of Columbia. One survey was completed per facility and responses were anonymous.

Results: The return rate was 33% (356 surveys). Results revealed comprehensiveness of the test battery varied among facilities. Over half of the respondents, 146 (55%), reported using a limited test battery, 94 facilities reported using a comprehensive test battery, but lacked at least one component recommended by the Joint Committee on Infant Hearing (JCIH), and 25 facilities reported using a test battery that met JCIH recommendations. Wait time for an appointment varied between facilities (range 3 days to 5 months), and was affected by the test condition (i.e., natural sleep, sedation, operating room).

Conclusions: Results suggested it is difficult for stakeholders to identify pediatric audiology facilities that serve infants less than six months of age. Results also revealed variability among facilities in test batteries and wait times for an appointment. Implications exist for diagnostic accuracy and timeliness of diagnosis.

Newborn hearing screening has become a standard of care over the past decade; yet, there remain barriers in effectively connecting parents to appropriate assessment services in a timely manner. A parent survey on infant diagnostic hearing assessment (N = 416) conducted in 2010 provided valuable insight into what parents have experienced, as the following example from one parent whose infant was born in 2009 illustrates (Larsen, Muñoz & DesGeorges, 2011).

The audiologist who performed my child's ABR simply referred us back to our pediatrician, who has little practical experience with hearing loss…What we really needed was a pediatric audiologist who could explain the diagnosis, begin the hearing process, and give us specifics as to the other specialists we needed to see as well as print/internet/community resources. We basically found all that for ourselves…I understand that the hospital techs who do the screening don't have the expertise to make a diagnosis, but we saw an audiologist for an OAE after two failed automated ABR's. My daughter failed that test [automated ABR] at 80db bilaterally (we were not told the level at the time of the exam). The audiologist could have told us then that it is HIGHLY likely that she is deaf, but instead she simply said "she needs an ABR, your pediatrician needs to order it". In my opinion, screening programs should only refer patients for definitive testing to audiologists who are competent to make a diagnosis and appropriately educate and direct the family in cases where a hearing loss is confirmed or highly suspected. This probably means they should have experience working with deaf young children.

The Centers for Disease Control and Prevention (CDC) reported that in 2005 and 2006 92% of newborns were screened for hearing loss prior to hospital discharge; however, for those babies who failed the screening, the state Early Hearing Detection Intervention (EHDI) programs were unable to document the diagnostic findings for 65% of the infants (Gaffney, Green, & Gaffney, 2010). This demonstrates the need to address loss to follow-up/documentation and to identify effective ways to assist parents in accessing diagnostic services (American Speech-Language-Hearing Association (ASHA), 2008).

When an infant fails newborn hearing screening, the Joint Committee on Infant Hearing (JCIH) recommends the completion of a comprehensive diagnostic hearing test no later than 3 months of age (JCIH, 2007). Diagnostic testing provides the necessary detail to know if a hearing loss exists, and, if so, the type, degree, and configuration of the hearing loss. This information is the foundation from which medical and educational intervention decisions are made. Specific recommendations regarding the test battery are provided in the JCIH 2007 Position Statement as shown in Table 1. The use of any single test to confirm hearing sensitivity is insufficient and is not consistent with recommended best practices (ASHA, 2008; JCIH, 2007). The physiologic assessment is particularly important in providing accurate estimates of hearing threshold sensitivity in infants. The electrophysiologic test battery should include ear-specific auditory brainstem response (ABR) testing using frequency-specific stimuli, such as tone bursts (ASHA, 1999). Bone-conduction ABR measures should be obtained to assist in identifying potential middle ear pathology, and use of a click stimulus for evaluation of neural integrity and the presence of the cochlear microphonic should be completed to

assist in differentiating between cochlear and neural dysfunction (ASHA, 2004; Berlin et al., 1998). In addition, the test battery should include otoacoustic emissions (OAE) to assess preneural auditory function (Gorga et al., 1993; Kemp, Ryan, & Bray, 1990), as well as tympanometry using a high frequency probe tone to measure middle ear function (ASHA, 1988; Holte, Margolis, & Cavanaugh, 1991).

Behavioral testing can be difficult to obtain in infants up to 6 months of age due to developmental and maturational factors. It should be noted that Behavioral Observation Audiometry (BOA) is included in the JCIH 2007 recommended protocol; however, its intended use is as a crosscheck, not for obtaining hearing thresholds: "Behavioral observation alone is not adequate for determining whether hearing loss is present in this age group, and it is not adequate for the fitting of amplification devices" (p. 905). However, after age 6 months, it is possible to obtain reliable responses using a visually reinforced behavioral response technique. As children get older, other behavioral techniques, such as play audiometry, can be used to obtain frequency-specific threshold information. However, an inclination to wait until the child is old enough to obtain frequency-specific behavioral responses results in unnecessary delays and significant time lost in the child's critical window of early development. Physiologic measures can provide accurate and reliable hearing sensitivity information and should be utilized as per JCIH recommendations. There are no advantages to delaying hearing intervention, as hearing aid fitting protocols designed for infants are available as guidelines to assist professionals in appropriate fitting techniques (American Academy of Audiology Pediatric Amplification Protocol, 2003; Kuk & Marcoux, 2002; The Pediatric Working Group, 1996; Seewald & Scollie, 2003; Seewald & Scollie, 1999).

Parallel to the importance of timely diagnostic testing is the implementation of timely early intervention services. Research shows that through early identification, appropriate use of hearing technology, and family-centered early intervention services with properly-trained professionals, children with hearing loss experience better language, speech, cognitive, and social-emotional development than later-identified children who did not benefit from early intervention services (Kennedy, et. al., 2006; Moeller, 2000; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). For example, results from a comprehensive longitudinal study in Colorado on the impact of early identification of hearing loss showed that children who were identified early and received prompt intervention services had significantly better vocabulary, language abilities, speech intelligibility, phoneme repertoires, syntax, social-emotional development, parental bonding, and parental grief resolution (Yoshinaga-Itano, 2003). Unfortunately, although efforts to identify and evaluate hearing loss in infants and young children have improved, there is evidence to suggest that many children with hearing loss may not be receiving the early intervention services they need in a timely manner that will enable them to enter school ready to succeed (National Center for Hearing Assessment and Management, 2010).

The provision of timely and comprehensive diagnostic testing following a failed hearing screening directly impacts the developmental window of opportunity and the parent's ability to capitalize on the time provided by early identification. Given the importance of access to comprehensive infant diagnostic testing, Windmill & Windmill (2006) investigated services available in Kentucky and found variability in testing among facilities that were listed as providers of infant diagnostic testing. Of the 42 facilities

listed, 34 reported that they provided testing for infants. Of these facilities, 12 reported using high frequency tympanometry, and 24 provided ABR testing. Of the facilities that conduct ABR testing, 10 used frequency specific stimuli. When the complete test battery was considered, only 3 (8%) facilities provided infant diagnostic test batteries that met the JCIH recommendations.

The purpose of this study was to gain a better understanding of current practice patterns nationally for infant diagnostic hearing assessment services provided by facilities identified as providers of pediatric diagnostic testing. By understanding existing challenges, stakeholders in the EHDI process can be better equipped to identify and address program improvement needs.

Method

Study Design

This study used a cross-sectional survey design. State EHDI coordinators from all states were invited by email to participate in distribution of the survey. Twenty-nine EHDI coordinators agreed to participate by mailing the surveys to all of the facilities in their state that self-reported the ability to provide infant hearing testing services. In August of 2009 surveys were mailed to 1091 facilities in 28 states and the District of Columbia. Surveys were collected through November of 2009. The study methods were reviewed and approved by the Utah State University institutional review board.

Survey Development

A team of three pediatric audiologists with expertise in infant diagnostic hearing assessment developed the survey. The survey questions were formulated and the survey was piloted with five pediatric audiologists for face validity. The survey was anonymous

and consisted of 12 questions designed to capture practice patterns and challenges (Appendix).

Participants

The surveys were mailed by the state EHDI coordinators with the instruction for one survey to be completed by each facility. Two reminder postcards were mailed two and four weeks respectively after the initial mailing. The reminder postcards provided a link to complete the survey online in the event the recipient no longer had the original paper survey.

Results

Of the 1091 surveys mailed, 356 were returned (33% response rate). Of those returned, 18 facilities did not provide any type of infant testing, and 34 facilities provided only screening services for infants. Therefore, surveys were received from 304 facilities (28% response rate) that do pediatric diagnostic hearing testing. The infant diagnostic testing practice patterns from the 304 reporting facilities are summarized in this report. The majority of testing was provided at hospitals (39%), medical clinics (23%), and private practices (23%). Other types of facilities included university clinics, public school audiology, departments of health, nonprofit centers, and medical schools.

Diagnostic Test Battery Components

Responses to the survey revealed that audiology facilities have different test batteries in place to provide infant diagnostic testing. To capture the differences in comprehensiveness of testing, the reported test batteries were categorized into five groups: (1) partial battery, (2) incomplete battery, (3) comprehensive battery, (4) JCIH recommended battery, and (5) extensive battery.

(1) Partial test battery (n = 45): these facilities reported a test battery consisting of high frequency tympanometry, otoacoustic emissions (OAE), and click ABR testing. These centers did not report obtaining frequency specific ABR thresholds.

(2) Incomplete test battery (n = 101): these facilities reported a test battery that included frequency specific test procedures; however, they omitted one or more of the following key diagnostic test procedures: high frequency tympanometry, OAE, click ABR, bone conduction ABR, a low or high frequency tone burst. The percent of facilities that omitted each individual test component is reported in Table 2. The percent of facilities that omitted one or more test components (i.e., 1 test, 2 tests, 3 tests, 4 tests, 5 tests) from their test batteries is reported in Table 3.

(3) Comprehensive test battery (n = 94): these facilities included all tests indicated in the JCIH 2007 guidelines, except one or more of the following: behavioral observation audiometry (BOA) (omitted by 74% of the facilities), cochlear microphonic (CM) (omitted by 50% of the facilities), and use of auditory steady state response (ASSR) instead of toneburst ABR for frequency specific thresholds (substituted by 10% of the facilities).

(4) JCIH 2007 recommended test battery (n = 13): these facilities reported using all of the components recommended by the JCIH 2007.

(5) Extensive test battery (n = 12): these facilities included all of the JCIH recommended tests plus one or more of the following: high frequency acoustic reflex testing, additional toneburst frequencies, and/or ASSR testing.

ABR Testing Conditions

The auditory brainstem response component of the test battery is done in one of three different test conditions: during natural sleep, under conscious sedation, or under general anesthesia in the operating room. Results indicated that 97% of the facilities offered ABR testing during natural sleep (n = 296), 37% offered ABR testing under sedation (n = 113), and 44% offered ABR testing in the operating room (n = 133). The respondents were asked to estimate the typical age of infants when tested using natural sleep ABR and the minimum age of infants when tested using conscious sedation or general anesthesia in the operating room. The differences in age of testing as a result of test condition are shown in Table 4. The amount of time it takes to get an appointment can vary by the test condition; therefore, respondents were asked to report the wait time for the next three available appointment times for each test condition offered at their facility. The data for the third available appointment time for each test condition is summarized in Table 5. Studies have shown that the third next available appointment is most representative of the typical wait time (Institute for Healthcare Improvement, nd).

When an infant is being assessed in a natural sleep state, sufficient time is needed for testing. The length of the appointment can affect the ability to complete a comprehensive test battery. Results indicated that the median appointment length was 2 hours (range 30 minutes to 4 hours). The baby needs to remain sleeping during the ABR; if the baby is awake or moving, interfering muscle noise embedded in the ABR tracing contaminates the results. Respondents were asked to report approximately how frequently they were unable to complete testing during the previous six months due to muscle movement noise. The percent of time this occurred for facilities is reported in Table 6. When testing cannot be completed during the appointment, repeat or additional testing

may be needed. Repeating testing procedures to verify results can provide additional useful information in some cases, but it can also delay definitive diagnosis if there are delays between appointments. Respondents were asked approximately how frequently they repeated testing to verify results over the previous six-month period. The percent of time this occurred for facilities is reported in Table 7; several respondents indicated that they routinely repeat the testing on all babies with hearing loss. Providing instructions to parents for a natural sleep ABR can improve the likelihood of a successful testing session; the instructions used by facilities are reported in Table 8. Other instructions included bringing the baby inside in the car seat; not letting the baby sleep during the car ride to the facility; not bringing siblings; feeding the baby on arrival; and scheduling the appointment during normal naptime.

When facilities use conscious sedation for ABR testing the minimum age established by each facility can affect the timeliness of the evaluation. The youngest age in which an infant could be sedated for the purpose of performing a diagnostic hearing test differed among respondents. Results indicated that the median minimum age facilities will sedate was 6 months (range 1 to 24 months). There are risks associated with sedation and for this reason specific guidelines exist for medical monitoring throughout the procedure. Results indicated that of the 113 facilities that offer sedated ABR testing, 96 facilities provided nurse/physician monitoring for sedated ABR testing, 5 facilities indicated that they did not provide monitoring, and 12 facilities did not provide monitoring information. Sedation agents most commonly used were chloral hydrate (n = 73), and propofol (n = 18). Facilities were asked approximately how often they could not get all needed test information when they did the ABR under sedation during the past six

months. The percent of time reported by facilities is shown in Table 9. The number of facilities that were unable to obtain reliable threshold information more than 50% of the time was similar for both natural sleep and when using a conscious sedation procedure. Respondents indicated that the medical staff was very supportive of assisting with sedation for ABR procedures for 93 facilities, somewhat supportive for 15 facilities, and not supportive for 3 facilities.

Completing the ABR test in the operating room may be a preferred option for a variety of reasons. Respondents reported using this test condition for infants with special needs (n = 79), for infants who cannot be sedated using a conscious sedation procedure (n = 54), and for infants undergoing additional procedures (n = 116). Some facilities (n = 38) reported testing all infants over a certain age in the operating room. The median age reported was 6 months (range <1 month to 24 months). Facilities that perform ABR testing in the operating room were asked how supportive their medical staff is of this procedure. Results indicated that medical staff was very supportive for 103 facilities, somewhat supportive for 28 facilities, and not supportive for 2 facilities.

Challenges

Respondents reported that it is challenging to test infants by 3 months of age for a variety of reasons. As seen in Table 10, the most common challenges reported were related to scheduling and medical issues. Other challenges reported by respondents included staffing problems, reimbursement, and no shows for appointments.

Study Limitations

There were several limitations to this study. Even though pediatric audiology facilities in 28 states and the District of Columbia were sampled with recruitment of a fair

number of participants (356), the response rate of 33% was relatively low. However compared with other national surveys, this response rate is not unusually low. For example, a national survey of audiologists regarding their pediatric hearing aid fitting practices had a response rate of 27% (Tharpe, Fino-Szumski, & Bess, 2001), and a national survey of pediatricians regarding their practices for treating otits media had a response rate of 22% (Danhauer, Johnson, Rotan, Snelson, & Stockwell, 2010). Mechanisms for the identification of pediatric audiology facilities vary by state, and are often based on self-report. Given this, the responses may be biased towards the facilities that are more aware of, or involved in follow-up testing after failure to pass newborn hearing screening. If this is the case, then the inconsistencies in reported test batteries among facilities are more surprising, because one might expect that those with more interest in serving infants would be better informed about best practices. As this was an anonymous survey, it was not possible to contact respondents and clarify responses; therefore, the risk exists that respondents may have misunderstood a question and the response is not accurate. Furthermore, this study did not attempt to measure the knowledge of audiologists in providing diagnostic services to infants.

Discussion

Newborn hearing screening provides parents with the opportunity to initiate intervention in a timely manner to maximize their child's language development and subsequent potential for age-appropriate academic achievement. Time lost following a failed newborn hearing screening cannot be recovered, and difficulty identifying where to get a comprehensive diagnostic hearing assessment can contribute to delays in intervention.

The responses to this study suggested that it might be difficult for some families to identify pediatric audiology facilities that provide services for children less than six months of age. State EHDI coordinators mailed the survey to facilities in their state that they believed to be pediatric facilities; however, the responses revealed that 5% did not provide any infant testing, and 10% provided only screening services for infants. Some states have compiled a directory of pediatric audiology facilities to assist parents in identifying a facility for follow-up; however in a review of testing capabilities listed in the directories for three states (NCHAM, n.d.) one quarter to one half of the facilities listed did not provide any testing for infants less than six months of age, and an additional one third only had screening capabilities. This illustrates the difficulty parents' encounter when searching for an appropriate facility for diagnostic assessment.

Of the facilities in this study that provided diagnostic testing for infants, practice patterns were found to vary from one facility to another. One area of variability was the comprehensiveness of the test battery. Omission of tests from the JCIH recommended test battery can lead to an incomplete understanding of the hearing loss and contributes to misdiagnosis and mismanagement. Forty-eight percent of the facilities in this study reported use of an inadequate test battery. Similarly disturbing, in a review of the pediatric facilities directories posted online (NCHAM, n.d.), the list for a state that outlined testing capabilities for each facility revealed that 21% of the facilities on the list provided an incomplete test battery. Without clear guidance, a parent may not be able to fully understand the differences in testing capabilities between facilities.

In order to complete a comprehensive evaluation, testing should be done while the infant is sleeping, and an appointment time of sufficient length is needed. Typically a

two-hour appointment has been found sufficient for this purpose (Karzon & Lieu, 2006). For some facilities the appointment length was as short as 30 minutes. A second area of variability was the wait time for an appointment. At some facilities the wait time was as long as 3 to 5 months. An excessive delay in appointment availability impinges on the intervention process, and can be a source of frustration for parents seeking services for their child. The condition under which ABR testing is available (i.e., natural sleep, sedation, operating room), and the need for repeat testing were additional areas of variability. Some facilities experienced significant difficulty with ABRs that contained excessive noise. The reason for this was not investigated as part of this study, but may be related to the skills of the audiologist, or an insufficient amount of time allowed for the appointment.

Efforts to provide educational outreach on infant diagnostic testing procedures exist for audiologists, for example, through conference presentations and focused workshops with hands-on practice. The effectiveness of these efforts to change practice patterns is not known. As shown by the results of this study, even though there are guidelines for infant hearing assessment (JCIH, 2007; ASHA, 2004) there exists variability in reported test protocols among clinics. It is clear that comprehensive testing that leads to a thorough understanding of hearing status is critical. Why then, is there a lack of consistency? Some explanations may include factors such as, a lack of appropriate equipment to complete all of the testing; a lack of expertise in pediatric assessment; logistical barriers such as time restraints; or purposeful clinical decisions that drive inclusion/exclusion of specific tests in the battery. This study did not explore the reasons for variations and further investigation is needed to fully understand the reasons behind

differences in protocols. Future directions for research include exploring the knowledge, experience, and comfort levels of audiologists who are providing pediatric diagnostic testing; the knowledge and skills pre-professionals in audiology have related to infant diagnostic testing when they finish their degree; the barriers audiologists encounter in the work place to provide appropriate testing; the challenges parents encounter in the evaluation process after a failed NHS; and the barriers in connecting parents to intervention services once a hearing loss is identified.

Educational outreach is also needed for the child's medical home provider. The primary care physician (PCP) has an important role in connecting parents to a pediatric audiologist for a timely and comprehensive hearing evaluation. The PCP serves as the care coordinator and assists in connecting the family to appropriate services following a failed NHS (American Academy of Pediatrics, n.d.) Physicians have reported that they are comfortable talking to parents about the importance of NHS, but are less comfortable in knowing what to do next when a baby fails the screening, and lack confidence in discussing issues related to management of hearing loss (Moeller, White, & Shisler, 2006). Audiologists are uniquely positioned to provide ongoing information and support for the physician on topics related to EHDI. It is important for audiologists to keep in mind that physicians have busy schedules, and typically see few children with permanent hearing loss in the course of their practice. Physicians report that they would like information that is evidence-based, short and concise, that uses terminology familiar across disciplines delivered in a format that is familiar to them (e.g., grand rounds), and to have easy access to educational materials for parents (Muñoz, Shisler, Moeller, & White, 2009).

The rapid expansion of newborn hearing screening has created widespread demand not only for continuing education, but also for stakeholders to have timely access to information in order to effectively support families throughout the follow-up process. A study that investigated EHDI coordinators' experiences with follow-up after a failed NHS identified barriers in four general categories "(1) lack of service-system capacity; (2) lack of provider knowledge; (3) challenges to families in obtaining services; and (4) information gaps (p. S21)" (Shulman, Besculides, Saltzman, Ireys, White, & Forsman, 2010). An information infrastructure that allows the PCP timely access to NHS results, and follow-up diagnostic results would improve the effectiveness and efficiency of care management (Downing, Zuckerman, Coon, & Lloyd-Puryear, 2010). Physicians and professionals in audiology, speech-language pathology, deaf education, and early intervention are challenged to work together to support families and help each child reach their full potential through timely and appropriate diagnosis and intervention.

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References

American Academy of Audiology (2003). Pediatric Amplification Protocol. (2011, January 31). Retrieved from http://www.audiology.org/resources/documentlibrary/Documents/pedamp.pdf

American Academy of Pediatrics (n.d.). National Center for Medical Home Implementation: Early Hearing Detection and Intervention (EHDI). (2011, January 31). Retrieved from http://www.medicalhomeinfo.org/how/clinical_care/hearing_screening/

American Speech-Language-Hearing Association (2008). Loss to follow-up in Early Hearing Detection and Intervention [Technical Report]. (2011, January 31). Retrieved from http://www.asha.org/policy doi:10.1044/policy.TR2008-00302

American Speech-Language-Hearing Association (2004). Guidelines for the audiologic assessment of children from birth to 5 years of age. (2011, January 31). Retrieved from http://www.asha.org/policy doi:10.1044/policy.GL2004-00002

American Speech-Language-Hearing Association (1999). Guidelines: Competencies in auditory evoked potentials measurement and clinical applications. *ASHA Supplement, 19*, 23–28.

American Speech-Language-Hearing Association (1988). Tutorial on tympanometry. ASHA Working Group on Aural Acoustic-Immittance, Measurements Committee on Audiologic Evaluation. *Journal of Speech and Hearing Disorders, 53*, 354–377.

Berlin, C.I., Bordelon, J., St. John, P., Wilensky, D., Hurley, A., Kluka, E., & Hood, L.J. (1998). Reversing click polarity may uncover auditory neuropathy in infants.

Ear and Hearing, 19 (1), 37-47.

Danhauer, J.L., Johnson, C.E., Rotan, S.N., Snelson, T.A., & Stockwell, J.S. (2010). National survey of pediatricians' opinions about and practices for acute otitis media and xylitol use. *Journal of the American Academy of Audiology, 21* (5), 329-346.

Downing, G.J., Zuckerman, A.E., Coon, C., & Lloyd-Puryear, M.A., (2010). Enhancing the quality and efficiency of newborn screening programs through the use of health information technology. *Seminars in Perinatology, 34* (2), 156-162. doi:10.1053/j.semperi.2009.12.005

Gaffney, M., Green, D., & Gaffney, C. (2010). Newborn hearing screening and follow-up: Are children receiving recommended services? *Public Health Reports, 125* (2), 199-207.

Gorga, M.P., Neely, S.T., Bergman, B., Beauchaine, K., Kaminski, J., Peters, J., & Jesteadt, W. (1993). Otoacoustic emissions from normal-hearing and hearing-impaired subjects: Distortion product responses. *Journal of the Acoustical Society of America, 93* (4 Pt 1), 2050-2060.

Holte, L., Margolis, R.H., & Cavanaugh, R.M. (1991). Developmental changes in multifrequency tympanograms. *Audiology, 30* (1), 1–24.

Institute for Healthcare Improvement: Third next available appointment. (2011, January 31). Retrieved from http://www.ihi.org/IHI/Topics/OfficePractices/Access/Measures/Third+Next+Available+Appointment.htm

Joint Committee on Infant Hearing (2007). Year 2007 Position Statement: Principles and

guidelines for early hearing detection and intervention programs. *Pediatrics,120* (4), 898-921.

Karzon, R., & Lieu, J. (2006). Initial audiologic assessment of infants referred from well baby, special care, and neonatal intensive care unit nurseries. *American Journal of Audiology, 15* (1), 14-24.

Kemp, D.T., Ryan, S., & Bray, P. (1990). A guide to the effective use of otoacoustic emissions. *Ear and Hearing, 11* (2), 93-105.

Kennedy, C.R., McCann, D.C., Campbell, M.J., Law, C.M., Mullee, M., Petrou, S., Watkin, P., Worsfold, S., Yuen, H.M., & Stevenson, J. (2006). Language ability after early detection of permanent childhood hearing impairment. *New England Journal of Medicine*, *354* (20), 2131-2141.

Kuk, F. & Marcoux, A. (2002). Factors ensuring consistent audibility in pediatric hearing aid fitting. *Journal of the American Academy of Audiology, 13* (9), 503-520.

Larsen, B., Muñoz, K., DesGeorges, J., Nelson, L. (2011). Challenges in obtaining an infant diagnostic diagnostic hearing evaluation. National EHDI Conference. Atlanta, GA.

Moeller, M.P. (2000). Early intervention and language development in children who are deaf and hard of hearing. *Pediatrics, 106* (3), E43.

Moeller, M.P., White, K., Shisler, L. (2006). Primary care physicians' knowledge, attitudes, and practices related to newborn hearing screening. *Pediatrics*, *118* (4), 1357-1370. doi: 10.1542/peds.2006-1008

Muñoz, K., Shisler, L., Moeller, M.P., & White, K. (2009). Improving the quality of early hearing detection and intervention services through physician outreach. *Seminars in Hearing, 30* (3). *184-192.*

National Center for Hearing Assessment and Management (2010). Early Intervention. (2011, January 31). Retrieved from http://www.infanthearing.org/earlyintervention/index.html

National Center for Hearing Assessment and Management (n.d.). The "state" of early hearing detection and intervention in the Untied States. (2011, January 31). Retrieved from http://www.infanthearing.org/states/index.html

Pediatric Working Group. (1996). Amplification for infants and children with hearing loss. *American Journal of Audiology, 5* (1), 53–68.

Seewald, R.C., & Scollie, S.D. (2003). An approach for ensuring accuracy in pediatric hearing instrument fitting. *Trends in Amplification, 7* (1), 29-40.

Seewald, R.C., & Scollie, S.D. (1999). Infants are not average adults: Implications for audiometric testing. *The Hearing Journal, 52* (10), 64-72.

Shulman, S., Besculides, M., Saltzman, A., Ireys, H., White, K., & Forsman, I. (2010). Evaluation of the universal newborn hearing screening and intervention program. *Pediatrics, 126*, Suppl 1 S19-27.

Tharpe, A.M., Fino-Szumski, M.S., & Bess, F.H. (2001). Survey of hearing aid fitting practices for children with multiple impairments. *American Journal of Audiology, 10*, 32-40.

Windmill, S., & Windmill, I.M. (2006). The status of diagnostic testing following referral from universal newborn hearing screening. *Journal of American Academy of Audiology,17* (5), 367-378.

Yoshinaga-Itano, C. (2003). From screening to early identification and intervention: discovering predictors to successful outcomes for children with significant hearing loss. *Journal of Deaf Studies and Deaf Education, 8* (1)*,* 11-30.

Yoshinaga-Itano, C., Sedey, A.L., Coulter, D.K., & Mehl, A.L. (1998). Language of early and later-identified children with hearing loss. *Pediatrics, 102* (5), 1161-1171.

Table 1

JCIH Recommended Infant Hearing Test Battery Components

Tympanometry using a 1000-Hz probe tone
Distortion product or transient evoked otoacoustic emissions
Click-evoked auditory brainstem response (ABR)
Identification of the cochlear microphonic from the click ABR
Frequency-specific assessment using tone burst ABR
Bone conduction ABR
Clinician observation of infant's auditory behavior

Table 2

Percent of facilities that omitted each test component in the incomplete test battery group (n = 101)

Test Component	%
Bone Conduction ABR	75
Cochlear Microphonic	71
Behavioral Observation Audiometry	66
High Frequency Tympanometry	30
Tone Burst: High Frequency	15
Otoacoustic Emissions	8
Click ABR	7
Tone Burst: Low Frequency	2

Table 3

Percent of facilities that omitted tests from the incomplete test battery group (n = 101)

Number of Missing Tests	%
Missing 1 test	10
Missing 2 tests	20
Missing 3 tests	26
Missing 4 tests	19
Missing 5 tests	3

Table 4

Test Condition and Age at Time of Testing

Test Condition	*n*	Median Age	Range
Natural Sleep			
Typical age at time of test	229	2 months	<1–24 mos.
Sedated			
Minimum age for testing	93	6 months	1-24 mos.
Operating Room			
Minimum age for testing	38	6 months	<1-24 mos.

Table 5

Wait time for ABR testing, third available appointment

Test Condition	*n*	Median	Range
Natural Sleep	265	19 days	3 days to 3 months
Sedation	93	30 days	4 days to 5 months
Operating Room	71	28 days	6 days to 4 months[a]

[a]Many of the facilities reported that the wait time for testing in the operating room could not be predicted as it is dependent upon physician availability

Table 6

Natural sleep: Number of facilities that could not complete testing due to noise during the previous six months

% of Tests	*n*
0%	99
1 to 10%	77
11 to 25%	33
26 to 50%	18
>50%	7

Table 7

Natural sleep: Number of facilities that repeated testing to verify results during previous six months

% of Tests	*n*
0%	53
1 to 10%	64
11 to 25%	43
26 to 50%	23
>50%	16

Table 8

Useful instructions to prepare parents for ABR testing

Instructions	*n*
Bring infant sleep deprived	272
Bring infant hungry	257
Bring items to comfort infant	232
Do not put lotion on the infant's face	62
Other	16

Table 9

Conscious sedation: Number of facilities that could not complete needed testing during previous six months

% of Tests	*n*
0%	6
1 to 10%	37
11 to 25%	7
26 to 50%	5
>50%	6

Table 10

Challenges to completing diagnostic testing prior to 3 months of age

Challenge	Frequency
Parent compliance in scheduling	212
Presence of middle ear fluid	179
Infants having other medical/health issues	143
Parents live far from facility	105
Noisy results, repeat testing needed[a]	104
Parents have transportation problems	102
Lengthy waiting time for appointments	97
Receiving timely referrals from screening	85
ABR testing only done under sedation	6

[a]Results are noisy when the baby is not asleep for the test. Noise is generated by muscle movement artifact and can obliterate a response and interfere with interpretation of results.

Appendix

INFANT DIAGNOSTIC HEARING EVALUATION SURVEY

We need your help to improve infant diagnostic hearing evaluations following failure of their newborn hearing screening. Please take ten minutes to tell us about your experiences. We are seeking to improve timely access to diagnostic testing. Audiologists are central to the completion of this important step in the EHDI process. Your responses are completely confidential and will be used to improve services to infants suspected of hearing loss. Please return the survey in the enclosed envelope. Your participation is greatly appreciated.

Q1. What type of setting is your facility?

_____ Hospital _____ Medical Clinic _____ Private practice
_____ Other (specify):

Q2. What state is your facility located in? _____

Q3. What is the average number of diagnostic hearing evaluations your facility performs each month for the following age groups:

_____ Birth – 6 mo _____ 7 mo – 2.11 yrs _____ 3 – 5 yrs

Q4. Indicate the tests included in your **standard infant** (birth to 6 mo) diagnostic test battery:

___ **High frequency tympanometry** ___ **Bone conduction ABR**
___ **High frequency acoustic reflex** ___ **ASSR**
___ **Otoacoustic emissions** ___ **Behavioral Observation Audiometry**
___ **Click ABR** ___ **Other (specify):**
___ **Cochlear microphonic**
___ **Toneburst ABR:** ___ **250 Hz** ___ **500 Hz** ___ **1K Hz** ___ **2K Hz** ___ **4K Hz**

Q5. Which of the following infant ABR services are offered at your facility?
___ ABR during **natural sleep**
During the past six months, how many ABRs were performed during
natural sleep? _____
What is the average age of the infant at the time of testing? _____
How much time is scheduled for each appointment? _____

___ ABR under **sedation**

During the past six months, how many ABRs were performed under sedation? _____

At what age does your facility typically recommend sedated testing? _____

Is a nurse available to monitor the baby during the procedure?

___ Yes ___ No

___ ABR in the **operating room**

During the past six months, how many ABRs were performed in the operating room? _____

Which of the following categories of infants do you perform testing in the OR?

___ All infants over the age of _____ months
___ Infants with special needs
___ Infants who cannot be safely sedated using a conscious sedation procedure
___ Infants who are undergoing additional procedures (e.g., insertion of tubes)

Q6. Indicate below, the challenges <u>you experience at your facility</u> related to completing diagnostic evaluations **prior to three months of age**:

___ **Receiving timely referrals from screening** ___ **ABRs done only under sedation**
___ **Parent compliance in scheduling** ___ **Parents have transportation problems**
___ **Infants having other medical/health issues** ___ **Presence of middle ear fluid**
___ **Appointments booked out several weeks** ___ **Parents live far from the facility**
___ Noisy results, repeat testing is needed ___ Other (specify): _____

Q7. In order to help us understand typical wait times for ABR appointments at your facility, please check your schedule and indicate available appointment dates for the following scenario: **PLEASE ENTER TODAY'S DATE _____**

Natural Sleep ABR

If a family were to call your facility today for an ABR appointment during **natural sleep**, what is the next available appointment? _____ If the family had a conflict with that appointment time, what is the next available date? ____ If the family had a conflict with that date what would be the next available date? _____

Sedated ABR
If a family were to call your facility today for an appointment for a **sedated ABR**, what is the next available appointment? _____ If the family had a conflict with that appointment time, what is the next available date? ____ If the family had a conflict with that date what would be the next available date? _____

Operating Room ABR
If a family were to call your facility today for an ABR appointment in the **operating room**, what is the next available appointment? _____ If the family had a conflict with that appointment time, what is the next available date? ____ If the family had a conflict with that date what would be the next available date? _____

Q8. During the past six months, approximately what percent of the ABR's performed during **natural sleep**:
Could not be interpreted due to excessive muscle movement noise? ____
_____
Needed to be repeated to verify results? _____

Q9. Indicate the instructions you have found most helpful to successfully complete your test battery when testing an infant during **natural sleep**:
____ Bring infant sleep deprived (tired and ready to sleep)
____ Bring infant hungry (ready to eat)
____ Bring items to comfort infant (e.g., pacifier, bottle, blanket)
____ Do not put lotion on the infants face
____ Other (specify):
_____

Q10. What is typically used at your facility for sedation?
___ Chloral hydrate ___ Other (specify):
_____

Q11. During the past six months, for approximately what percentage of the ABR's **under sedation** were you <u>unable</u> to get all of the diagnostic information needed? _____

Q12. Please rank how supportive your medical staff is in assisting you to provide:
1 = not supportive 2 = somewhat supportive 3 = very supportive

ABRs under sedation:	1	2	3
ABRs in the operating room:	1	2	3

Thank You!