Audiologic Clinical Practice Patterns: Infant Assessment

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Abstract

The purpose of the present study was to report the current clinical practice patterns for assessment of infants after a referred newborn hearing screening within the context of available guidelines and to examine how the advent of newer stimuli, technology, and/or instrumentation has changed clinical practice patterns for audiologic infant assessment. A mixed-method survey that included both quantitative and qualitative questions was disseminated to pediatric audiologists in 2017. Quantitative data were analyzed via descriptive statistics while qualitative questions were analyzed via content analysis and combined with associated quantitative data. Lastly, infant assessment test battery categorization was completed to ascertain the extent to which providers were using recommended protocols. Results revealed appreciable variability in the test batteries employed by facilities evaluating infants. Additionally, a sizable portion of facilities are not using test batteries recommended by sources of guidance for evidence-based practice, suggesting a possible need for adopting a standardized protocol in the United States. Factors that potentially contribute to these results are reviewed as well as proposed next steps toward improving adherence to recommended guidelines.

Acronyms: ABR = automated brainstem response; ANSD = auditory neuropathy spectrum disorder; ASSR = auditory steady state response testing; DPOAE = distortion product otoacoustic emissions; EHDI = Early Hearing Detection and Intervention; JCIH = Joint Committee on Infant Hearing; OAE = otoacoustic emissions

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Over the past decade, the rate of infants screened for hearing loss at birth, receiving diagnostic testing, and enrolled in EI services have all increased significantly (Subbiah, Mason, Gaffney, & Grosse, 2018). Although the screening rate quickly approached ceiling levels shortly after newborn hearing screening became universal in most states in 2005, successful completion of diagnostic testing and enrollment in early intervention services for children with confirmed hearing loss continues to lag behind (Grosse et al., 2017). One factor that might contribute to differences in follow-up rates across early hearing detection and identification (EHDI) programs is variability in how programs are executed across the United States. For screenings, each individual state mandates when testing occurs (solely as inpatient or allowing an outpatient screening) and the type of testing that occurs, which typically depends upon risk factors for hearing loss. Decisions for screening protocols are often based on recommendations from the Joint Committee on Infant Hearing, which allows for some variability in screening depending upon certain factors (JCIH, 2007). Despite the variability in how screening occurs from both a logistical and testing paradigm perspective, state EHDI systems have successfully achieved a high rate of screening prior to one month of age, with national data increasing from 85.1% in 2006 to 98.6% in 2016 (Subbiah et al., 2018). A potential reason for these success rates may be that defined screening procedures and protocols merely exist.

However, the high level of success seen at the screening step of EHDI programs has not translated to the diagnostic step of the process. Within the same time period, the percentage of infants receiving diagnostic assessment prior to three months of age increased from 19.8% in 2006 to 36.6% in 2016 (Subbiah et al., 2018). Although the overall percentage of infants receiving diagnostic assessment in general reached a high of 56.6% in 2016, state EHDI programs continue to struggle with executing the diagnostic step of the EHDI process. Reasons for delays between initial diagnostic testing and confirmation of hearing loss have included a need for multiple tests to confirm hearing status, recurrent middle ear issues, and near-normal hearing at initial testing or fluctuant hearing loss noted on serial tests (Fitzpatrick, dos Santos, Grandpierre, & Whittingham, 2017; Holte et al., 2012). Parents who have gone through the EHDI system have reported that multiple tests were needed for confirmation

of hearing loss and 29% of families reported a need to go to multiple locations for a complete testing (Larsen, Muñoz, DesGeorges, Nelson, & Kennedy, 2012). The need for multiple tests to confirm hearing status has been attributed to additional multiple factors, including inadequate sleep state limiting the number of threshold measures obtained, noisy test results precluding conclusive results, and the presence of chronic middle ear fluid (Muñoz, Nelson, Goldgewicht, & Odell, 2011).

An additional explanation for the need for multiple tests may be the lack of a defined expectation of diagnostic centers in terms of testing protocols or adoption of an expected protocol. Although some states have defined diagnostic protocols for infant assessment, many do not, and of those who have recommended protocols available to review there is significant variability in the level of detail provided to guide clinicians (Hunter, Steuerwald, Hounam, & Kothari, 2016). In contrast, diagnostic programs outside of the United States often have published protocols to define necessary testing procedures for diagnosing hearing loss in infancy at either the national or province-level (Hatton, Hyde, & Stapells, 2012; Hyde et al., 2016; Sutton et al., 2013). Although some guidance has been offered in the United States through governing body guideline statements (American Academy of Audiology [AAA], 2012; JCIH, 2007; JCIH, 2019) and by practitioners providing guidance articles (Smith & Wolfe, 2014), there continues to be no specific protocols mandated by a majority of EHDI programs.

The limited adoption of recommended, evidence-based protocols across the United States has led to significant variability in the provision of services. Munoz et al. (2011) systematically studied clinical practice patterns for infant assessment through a national survey. Findings of this survey revealed that only 9.4% of respondents were using an infant assessment battery consistent with JCIH (2007) recommendations, with the remaining 90.6% of facilities reporting assessment batteries of varying thoroughness (Muñoz et al., 2011). At that time, 16.9% of respondents reported using no frequency-specific electrophysiologic measures of hearing (i.e., automated brainstem response [ABR] using tone burst stimuli), which is considered to be essential given that the fitting of amplification for those children who are diagnosed with permanent hearing loss will be the next step in the process. Consequently, evaluations completed after a newborn hearing screening referral appear to vary considerably across facilities and states in general, which may significantly impact the national EHDI program effort to diagnose hearing loss in infants by three months of age.

An update to the JCIH statement was just released and continues to provide guidelines for diagnostic testing of infants and young children along with substantial evidence to support those guidelines (JCIH, 2019). Although this updated statement does not outline which diagnostic tests should take place within specific age ranges in the same manner as previous iterations, the statement outlines the key aspects of audiologic assessment for infants and young children as including the following: (a) auditory brainstem response testing to estimate ear- and frequency- specific thresholds to define type, degree, and configuration of hearing level, (b) tympanometry or wideband reflectance to assess middle ear function, (c) acoustic reflexes to evaluate middle ear and auditory brainstem pathway integrity, (d) otoacoustic emissions (OAE) to evaluate the integrity of the outer hair cell function of the cochlear, and lastly, (e) behavioral evaluation via visual response audiometry or conditioned play audiometry as soon as developmentally appropriate.

The purpose of the present study was to report the current clinical practice patterns for assessment of infants after a referred newborn hearing screening within the context of available guidelines. Additionally, we sought to examine whether the advent of newer stimuli, technology, and/or instrumentation has changed clinical practice patterns for audiologic infant assessment.

Method

This survey study was deemed exempt from review by the Nationwide Children's Hospital Institutional Review Board. The study was designed as a mixed-model survey that included both quantitative and qualitative questions collected electronically through REDCap (Harris et al., 2009). Survey development was modeled after a previously published clinical practice survey (Muñoz et al., 2011) after obtaining permission from the lead author (personal communication). Survey questions included information regarding tests completed as a part of assessment of both infants and young children, as well as testing conditions and logistics of scheduling wherever applicable. Survey questions were updated to provide choices that included modern assessment stimuli (chirp) and testing paradigms (auditory steady state response testing; ASSR) for the electrophysiologic questions. This paper will describe the infant assessment data only, focusing on diagnosis of hearing loss in children birth to six months of age. Once survey formulation was completed by the study team, questions were piloted with ten clinical audiologists currently engaged in assessment of infants and young children to evaluate whether questions were straight forward and answerable. The final survey is available for review in the Appendix.

Survey dissemination was completed over a two month time period from October to November 2017. Surveys were disseminated by direct email to 345 pediatric audiologists known to be currently providing care for infants and young children, social media posts on specialized pediatric audiology groups, and through communication via two EHDI program coordinators who were willing to provide the survey link to audiologists in their diagnostic networks. One EHDI coordinator also offered to post the survey announcement on an EHDI coordinator listserv for the United States to encourage other coordinators to disseminate the survey. During the course of the survey period, audiologists who were directly emailed were invited to participate in the survey twice (10/17/2017 and 11/1/2017) to facilitate completion of the

survey. The survey announcement was also posted twice during this time period on social media outlets (10/18/2017 and 11/1/2017). Because of the use of social media and listservs for dissemination, the total number of audiologists the survey reached cannot be calculated.

A total of 272 surveys were submitted during the data collection period; 187 (68.8%) were completed in full. Respondents reported practicing in 39 states and Washington, D.C. Most respondents reported they were female ($n = 173$, 92.0%) practicing in a hospital setting ($n = 101$, 54.1%). Other settings represented in the dataset included: private-practice ($n = 17$, 9.0%), college/university clinic ($n = 13$, 7.0%), ENT office ($n = 18$, 9.6%), school ($n = 19$, 102%), and other ($n = 19$, 10.2%). Most of the respondents reported having an AuD degree ($n = 146$, 78.6%) while 20 (10.6%) reported having a Master's degree, 17 (9.1%) reported having a PhD, one (0.5%) reported having ScD degree, and three (1.6%) declined to respond to this question. Most of the respondents reported having between one and five years ($n = 64$, 34.8%) or over 20 years ($n = 37$, 20.1%) of clinical experience. Respondents were also asked to report how many years of clinical experience they have specifically evaluating infants and children. Of the 187 respondents who provided this information, 27 (14%) reported that they had not spent their entire clinical career seeing pediatric patients, and all but five reported at least 1–5 years of experience evaluating children. The remaining five (2.6%) respondents did not choose to report their years of clinical experience with pediatric patients.

Once the survey period ended, all variables were exported into Microsoft Excel files for analysis. Quantitative questions were analyzed through descriptive statistics using IBM SPSS Statistics, Version 24 (IBM Corp; Armonk, NY). Qualitative responses, predominantly in the form of free-field comments throughout the survey, were individually analyzed using content analysis (Hsieh & Shannon, 2005; Krippendorff, 1980) to derive themes that could supplement the quantitative results. Quantitative and qualitative results were then merged for each section of the survey. Percentages were calculated for each diagnostic test reportedly performed by respondents completing the infant assessment portion of the survey. Test batteries that were reported for assessment of infants between birth to six months of age were classified as either meeting or not meeting the JCIH (2007) guidelines, which outlines the following tests should be completed in infants ages birth to six months: (a) Child and family history; (b) frequency-specific assessment of the ABR using air-conduction and bone-conduction tone bursts; (c) Click-evoked ABR testing using both condensation and rarefaction single-polarity stimulus, if there are risk factors for neural hearing loss or if there is no response on tone burst ABR; (d) distortion product otoacoustic emissions (DPOAEs); and (e) Tympanometry using 1000-Hz probe tone. Because of the advent of additional frequency-specific testing stimuli and procedures since the publication of the JCIH (2007) guidelines, respondents who reported doing frequency-specific chirp ABR or ASSR

testing were included as being adherent to the guidelines. Additionally, data were analyzed in light of the newly released JCIH (2019) statement which adds acoustic reflex testing as a key part of a diagnostic test battery in infants and children.

Lastly, a logistic regression was completed to evaluate the effects of geographical location, years of clinical experience, and appointment length allowed for completing a natural sleep ABR on the likelihood that providers are adherent to recommended guidelines for diagnostic assessment in infants. These specific factors were chosen for analysis due to their potential impact on whether a provider would follow recommended guidelines. For instance, depending upon the state in which the respondent is located and the presence of their specific EHDI program, some respondents may have more support or higher visibility of JCIH guidelines than others. For this analysis, due to variance in the number of respondents from individual states, location was collapsed from state-level to regional-level, including Northeast ($n = 22$), South ($n = 34$), Midwest ($n = 55$), and West ($n = 8$) regions consistent with the United States Census Bureau Regions and Divisions (U.S. Census Bureau, Geography Division, 2000). For the purposes of categorization, one respondent from Hawaii was included in the West region. Eight respondents declined to report their location and had to be excluded from the analysis. Years of clinical experience may impact the confidence of providers executing different aspects of a test battery or alternatively may impact which tests are completed depending upon provider bias for specific tests. Lastly, appointment length may impact a provider's decision process for which aspects of a test battery should be completed given the allotted time. Analysis was completed with adherence to the JCIH (2007) guidelines (categorical yes/no) as the dependent variable with two-sided p-values < 0.05 considered significant.

Results

A total of 162 survey respondents recorded which tests they typically complete as a part of a test battery assessing infants birth to six months of age. Table 1 provides the number and percentage of respondents reporting they complete each test. Overall, a vast majority of respondents are performing a case history (100%), 1000 Hz tympanometry (93.8%), DPOAES (94.4%), frequency specific ABR (74.0%), and click ABR (85.19%). Alternative frequency-specific electrophysiologic testing was also reported by some respondents: chirp ABR (8%), tone burst ASSR (14.2%), or chirp ASSR (4.3%). Overall, these data suggest that there is variability among clinicians in what they include in a test battery to assess hearing for infants after a referred newborn hearing screening.

Responses were further categorized into whether the test battery meets or does not meet JCIH (2007) guidelines. Results showed that 88 (54%) were adherent to the JCIH (2007) recommendations. Among the 74 respondents who were not meeting recommendations, a variety of tests were omitted: 36 (48.6%) omitted bone conduction

Table 1

Number and Percent of Respondents who Perform Each Test Measure as a Part of their Infant Diagnostic Test Battery

Test Measure	Number	Percent
Otoscopy	145	89.51
Case History	162	100
1000 Hz Tympanometry	152	93.83
226 Hz Tympanometry	25	15.43
Acoustic Reflex Testing	40	24.69
DPOAEs	153	94.44
TEOAEs	19	11.73
Click ABR	138	85.19
Tone Burst ABR	120	74.07
Chirp ABR	13	8.02
Bone Conduction ABR	98	60.49
Chirp ASSR	7	4.32
Tone Burst ASSR	23	14.20

Note. DPOAEs = distortion product otoacoustic emissions; TEOAEs = transient evoked otoacoustic emissions; ABR = auditory brainstem response; ASSR = auditory steady state response.

testing, 21 (28.4%) omitted all but OAE and Click testing, 7 (9.5%) omitted click and bone conduction testing, 6 (8.1%) omitted click testing, and 4 (5.4%) omitted tympanometry and/or OAE testing (Figure 1). Of note, 21 (12.9%) of respondents reported using no frequency-specific electrophysiologic testing in their test battery. The recent publication of the 2019 JCIH statement additionally includes acoustic reflex testing as a key aspect of pediatric assessment and provides evidence to support its use in infants. It should be noted that based on the results of this survey, over 75% of respondents would be non-adherent to the updated guidelines based on excluding acoustic reflex testing from their test battery alone.

Respondents were asked whether their individual state provides a protocol or guidance for the assessment diagnostic test battery. Of the 162 respondents, 111 (68.5%) reported that their state does provide either a protocol or guidance. Qualitative responses revealed significant variability in the types of guidance offered, including anything from recommending that both ears are tested as the only recommendation to referring providers to national organization best practice statements for guidance on test battery formulation. Additionally, multiple respondents commented that although a guidance statement from their state EHDI program exists, the recommendations are dated and in need of updating due to not being consistent with current best practice statements. The logistic regression to evaluate the potential effects of region, years of clinical experience, and appointment length on the likelihood that a provider is adherent to recommended guidelines was not significant (X^2 (10) = 5.353, p = 0.866).

Figure 1. *Pareto chart of omitted test battery items leading to a determination of non-adherence to the JCIH (2007) recommended guidelines for assessment of infants birth to six months of age.*
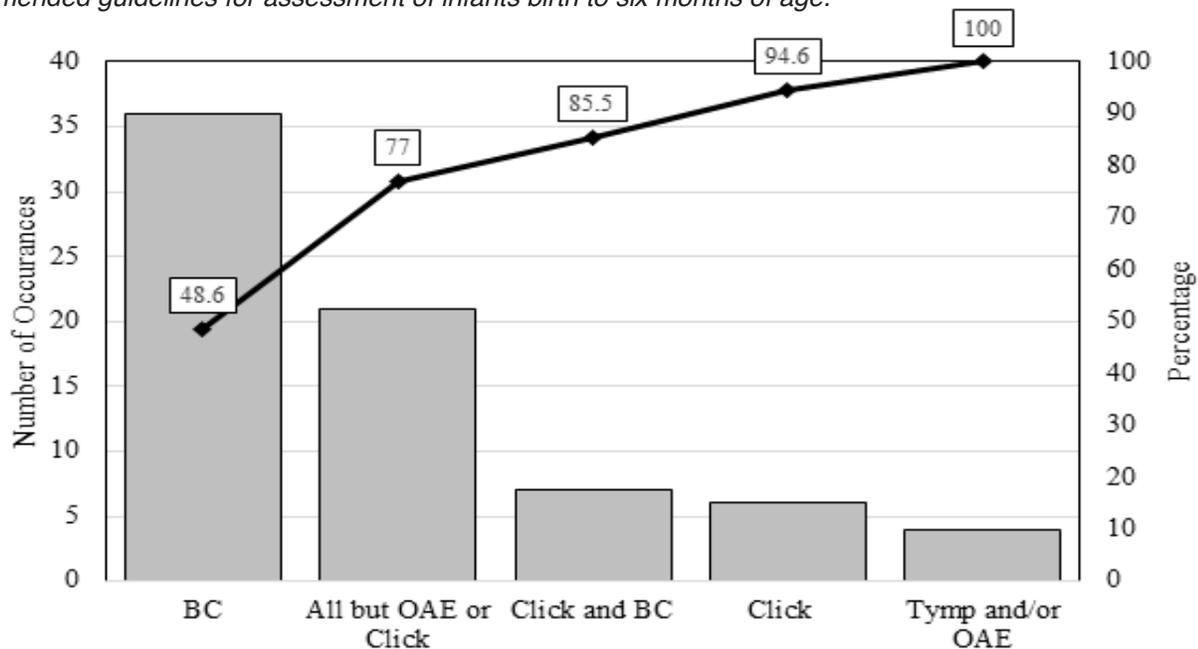
Note: BC = bone conduction; OAE = otoacoustic emissions; Tymp = tympanometry.

Test Conditions

In addition to respondents reporting which tests they performed as a part of their test battery, respondents were also asked a number of questions regarding test conditions or logistics. Parents were provided instructions for the test at 98.7% of facilities, but instructions varied and sometimes multiple channels were used. Respondents reported providing verbal instructions on the phone at the time of appointment scheduling (n = 123; 76.4%) and on the phone at the time of appointment confirmation (n = 72; 44.7%), or via a letter prior to the appointment (n = 110, 69.3%). Instructions included a number of different strategies to maximize sleep state (Table 2), with most respondents reporting they instruct families to bring the infant sleep deprived (n = 153, 95.6%) and hungry (n = 150, 93.8%).

Table 2
Number and Percent of Respondents Providing Specific Instructions to Parents for Preparation of Infant Natural Sleep Electrophysiologic Testing

Parental Instructions Provided	N (%)
Bring infant sleep deprived	153 (96.6)
Bring infant hungry	150 (93.8)
Bring items that comfort the infants (bottle, blanket, pacifier, etc.)	132 (82.5)
Bring an additional adult if planning on bringing additional children (older siblings) to the appointment	105 (65.6)
Bring an additional adult to help keep the infant awake during the car ride	95 (59.4)
Bring the car seat for them to sleep in for testing	45 (28.1)
Do not put lotion on the infant's face	40 (25.0)
Our facility provides no instructions prior to the appointment	2 (1.3)

A variety of appointment lengths were reported by respondents for performing a diagnostic ABR in natural sleep. Of the respondents who provided a response to this question (n = 161), 12 (7.4%) reported having a 60-minute appointment length, 28 (17.4%) reported 90 minutes, 93 (57.8%) reported 120 minutes, and the remaining 28 (17.4%) reported having 180–240 minutes to complete the test battery. Many respondents qualitatively added that this appointment length includes the time it takes for the infant to fall asleep for testing.

For test administration, a variety of starting points were reported for electrophysiologic measures, with most respondents reporting they start with click stimuli (n = 94, 62.3%) while others reported a variety of tone burst ABR or ASSR stimuli (Table 3). Comments included for this question indicated that some respondents start with a click to rule out auditory neuropathy spectrum disorder (ANSD) at the onset of the evaluation depending upon birth history or if the ABR was being conducted as a sedated

Table 3
Number and Percent of Respondents Reporting the Initial Stimulus for Electrophysiologic Testing of Infants

Stimulus	N (%)
Click ABR	94 (62.3)
2000 Hz tone burst ABR	36 (23.8)
4000 Hz tone burst ABR	11 (7.3)
1000 Hz tone burst ABR	4 (2.6)
2000 Hz chirp ABR	3 (1.9)
500 Hz chirp ABR	1 (0.7)
4000 Hz chirp ABR	1 (0.7)
Tone burst ASSR	1 (0.7)

Note. ABR = auditory brainstem response; ASSR = auditory steady state response

procedure, while using a 2K Hz stimulus for their starting point for non-sedated ABRs. Most respondents (n = 156, 98.7%) reported routinely using insert ear phones for their transducer versus standard/supra-aural TDH headphones (n = 2, 1.3%). Narrative comments included caveats for using supra-aural only for infants presenting with aural atresia/microtia. All respondents reported testing both ears regardless of screening results. In the case of unilateral referrals, 82.9% of respondents start testing in the ear that referred while 17.1% start testing in the ear that passed the newborn hearing screening.

Respondents were asked to report the top three factors that presented the most common challenges for completing a diagnostic evaluation in one appointment session (Table 4). The most common challenges were reported to be as follows: patient sleep state (n = 157, 98.7%), electrical noise interference during testing (n = 67, 42.1%), and equipment issues (n = 61, 38.4%). Narrative comments for this question included that it is rare to not complete testing within the allotted time (n = 5), the primary issue is the infant sleep state (n = 5), and additional factors were offered, including late arrival for the appointment (n = 5), neurologic issues leading to poor replicability (n = 1), a high no-show rate (n = 1) and parents not following directions for optimal testing (n = 1).

Table 4
Factors Related to an Inability to Complete a Diagnostic Evaluation Within One Appointment Session

Factors for Incomplete Tests	N (%)
Patient sleep state/waking up	157 (98.7)
Electrical noise interference	67 (42.1)
Equipment issues	61 (38.4)
Appointment time too short	44 (27.7)
Parent request to discontinue testing	27 (17.0)

Note. Respondents were requested to report the top three reasons

Discussion

The purpose of this clinical practice survey was to report the current clinical practice patterns for assessment of infants after a referred newborn hearing screening within the context of available guidelines. Results indicate that more clinicians report completing an infant test battery consistent with JCIH (2007) recommendations than previously reported on similar surveys conducted in a similar cohort of audiologists who complete assessments for infants who refer the newborn hearing screening (Muñoz et al., 2011). This is promising as EHDI programs across the United States strive to improve outcomes for children with congenital hearing loss by implementing interventions to increase adoption of recommended diagnostic follow-up and decrease loss-to-follow-up in this population. Despite the increase in evidence-based practice, significant variability in testing batteries and practices remain. Although there will always be patient-specific factors that exist which necessitate some flexibility in practice, having a consistent approach to diagnosis across test centers will reduce variability and increase equity of care for infants who refer on the Universal Newborn Hearing Screening. This survey indicates that there are several areas of commonality within assessment approach but also several areas of variability which may require further consideration for a unified approach across test centers.

Most respondents (98.7%) reported that they provide parental instructions for testing prior to the test day to optimize testing conditions. This is consistent with the previous data suggesting that clinicians recommend a variety of instructions to have parents prepare infants for optimal testing (Muñoz et al., 2011). Additionally, all respondents reported that they evaluate both ears during a diagnostic appointment regardless of the screening results (i.e., bilateral refer vs. unilateral refer). This finding is a positive practice considering hearing status might change in the time between screening and diagnostic testing and that human error could contribute to reporting results of ears erroneously. Both of these factors were mentioned by respondents in the narrative comments provided as a rationale for always testing both ears.

Despite improvements in evidence-based practice engagement, almost half of the respondents have not adopted recommended test batteries, and 12.9% of respondents report they do not use any frequency-specific electrophysiologic testing for their diagnostic assessments. Although the survey instructions were specific to diagnostic testing of infants birth to six months of age after a referred newborn hearing screening, results showed a large number of facilities engaging in re-screening approaches when perhaps a diagnostic evaluation was indicated. It is unclear as to whether these particular responses came from facilities within states that allow re-screening as an outpatient, or whether clinicians engage in re-screening despite state guidelines mandating a diagnostic after a pre-determined number of referred screens regardless of whether screenings were completed inpatient or in a hybrid approach of one inpatient and one outpatient screening.

Regardless of the source, results suggest a fair amount of re-screening in this population which may suggest a need for standardization in the definition of *diagnostic* assessment of hearing loss in infants. Although JCIH (2007), JCIH (2019), and the AAA Audiologic Guidelines for Assessment of Infants and Young Children (2012) Clinical Practice Guideline all state that there is a need for both a test battery approach and the use of frequency-specific electrophysiologic measures to infant assessment, it does appears that a number of clinicians who assess infants do not heed these recommendations. This is troubling given that another finding of this study was that emerging stimuli (chirp) and assessment methods (ASSR) are being employed by clinicians which would presumably give providers more flexibility in how they assess infants. Specifically, these newer testing approaches have been found to reduce test time due to elicitation of larger responses and concurrent measurement of multiple frequencies (Ferm, Lightfoot, & Stevens, 2013; Rodrigues, Ramos, & Lewis, 2013; Sininger, Hunter, Hayes, Roush, & Uhler, 2018).

Additionally, survey results revealed that clinicians are often starting their assessment using click stimuli despite the main objective of the assessment being to establish frequency-specific hearing sensitivity to evaluate whether intervention via amplification is necessary. Both JCIH (2007) and JCIH (2019) advocate for the prioritization of frequency-specific ABR assessment to establish frequency-specific hearing levels to guide fitting of amplification. Although assessment for neural integrity is important, especially for children with risk factors associated with possible neural involvement, less than 1% of the greater population will have findings of ANSD and only between 5 and 13% of children with permanent hearing loss will have results consistent with ANSD (Berlin et al., 2010; Vignesh, Jaya, & Muraleedharan, 2016; Rance, 2005; Sanyelbhaa, Kabel, Sammy, & Elbadry, 2009). Consequently, the assessment of neural integrity in cases in which there is a concern for ANSD is recommended by JCIH *after* risk factors and/or a no-response ABR has been established. Results of this clinical practice survey suggest that a majority of clinicians are not following clinical guidelines specific to which test among an infant test battery should be prioritized.

A lack of adherence to evidence-based practice is not a novel finding in our field. Other clinical practice surveys have indicated that clinicians are not following evidence-based practice guidelines specifically for the provision and management of amplification in children (Moodie et al., 2016). The current study continues to indicate that there is a significant need for improving adherence to recommended guidelines for evidence-based practice in the United States to ensure infants and young children are provided the hearing healthcare they need to optimize their outcomes in the presence of congenital hearing loss. To that end, there has been a recent push for more standardization at the state level (Hunter et al., 2018; Silver, 2019) and at the national level with continued revision of guidelines from national associations and

the formulation of the Audiology Standards Practice Organization. Although multiple factors can contribute to loss-to-follow-up after a referred newborn hearing screening, having a unified approach to assessment in infants can at the very least aid in increasing diagnostic follow-up. In countries where standards are set, follow-up for newborn hearing screening is considerably higher. Wood, Sutton, and Davis (2015) reported the advances made by the newborn hearing screening program in the United Kingdom between 2006 and 2013. Results showed that follow-up rates reached 82.5% for follow-up testing by 4 weeks of age and 95% follow-up testing prior to six months of age for the cohort of children born in late 2013 (Wood et al., 2015). Loss to follow-up rates are also lower in U.S. states that have established clinical protocols and/or state approval for diagnostic centers capable of providing infant assessment via ABR. California, Florida, Kansas, Massachusetts, Rhode Island, Vermont, Wisconsin, and Wyoming all have loss-to-follow-up rates less than 10% as of 2016 and have either a detailed state protocol or a system for state approval to be a diagnostic center specifically for ABR assessment (Centers for Disease Control and Prevention, 2018). Although there are many interventions that could be instituted to improve follow-up rates in the United States, until adoption of a unified approach to assessment in infants can be established it is unlikely that diagnostic follow-up rates after referral on newborn hearing screening will improve to meet peer-nation standards.

Although the data presented here reflect what pediatric audiologists reported as their diagnostic test battery for infants, one limitation of this study is the relatively small number of respondents which may not be reflective of the entire field. An attempt was made to evaluate whether specific factors affect the likelihood of a provider engaging in evidence-based practice as recommended by JCIH (2007) through logistic regression modeling; however, that analysis was not significant. It cannot be ruled out that this analysis was impacted by the small number of respondents or the variability in demographics and circumstances under which audiologists reportedly execute diagnostic testing. Additionally, direct comparisons with previous studies cannot be made due to potential differences in sample. In future studies, additional efforts should be made to ensure more consistent sampling across the United States through a structured, prospective, longitudinal study that would allow for direct comparison and evaluation of change across time.

Conclusion

Although engagement in evidence-based practice for infant hearing assessment has increased over the past several years, variability in testing protocols still exists. Facilitating the adoption of test batteries consistent with recommended national guidelines, especially if it is facilitated at the state-level in a similar fashion to screening procedures, may reduce this variability and serve to increase diagnostic rates after referral on the newborn hearing screening.

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Appendix

Audiology Infant Assessment Clinical Practice Survey

The Audiology Department at Nationwide Children's Hospital is conducting a survey of common clinical practices for infant assessment in the United States. The purpose of this survey is to explore how children are evaluated via electrophysiological and behavioral testing within the first 36 months of life.

This survey will take approximately 5-10 minutes to complete. Survey responses are anonymous and cannot be traced to individuals. This information will provide our field with important insight as to how we are providing services to this population. This study has been approved by the NCH Institutional Review Board (IRB 017- 00859).

For additional information about this survey, please feel free to contact the Principal Investigator, Dr. Ursula Findlen, for a Research Summary at ursula.findlen@nationwidechildrens.org.

Thank you for your consideration and time in completing this survey.

General Questions

Do you or does your facility provide assessment services to infants via electrophysiological (i.e.: ABR, ASSR, etc.) Testing?
- ○ Yes
- ○ No

Do you or does your facility provide assessment services for infants and young children via Visual Reinforcement Audiometry (VRA)?
- ○ Yes
- ○ No

State Early Hearing Detection and Intervention (EHDI) Programs

From the following choices, choose the response that best describes how much control that you feel you have/had on the development of your practice's protocol for testing infants and young children:

○ I have a lot of control over the protocol.
○ I can influence the protocol but ultimately the decision is out of my hands.
○ I have little/no influence on the protocol that is used in this practice.

Comment:

_____

Does your state Early Hearing Detection and Intervention (EHDI) program provide protocol recommendations for the following ages?

☐ For Testing children 0-6 months old
☐ For Testing children 6-12 months old
☐ For Testing children 12+ months old
☐ No recommendations are provided
☐ Unsure

Comment:

_____

If your state EHDI program provides a recommended protocol, does your practice's clinical protocol reflect the state recommended protocol?

○ Yes
○ No
○ Unsure
○ Not applicable

If your state EHDI program provides a recommended protocol, choose the response that best describes how much control that you feel you have/had on the development of that protocol:

○ I have a lot of control over the protocol.
○ I can influence the protocol but ultimately the decision is out of my hands.
○ I have little/no influence on the protocol that is used in this practice.
○ Not applicable

Comment:

_____

Electrophysiological Testing

Currently what is the length of appointment you have to complete an ABR/ASSR in natural sleep?

○ 30 minutes
○ 45 minutes
○ 60 minutes
○ 90 minutes
○ 120 minutes
○ Other (include length in comment section)

Comment: _____

Currently what is the length of appointment you have to compete a sedated ABR/ASSR in your department an/or the procedure center/OR?

○ 30 minutes
○ 45 minutes
○ 60 minutes
○ 90 minutes
○ 120 minutes
○ Other (include length in comment section)

Comment: _____

If an infant (0-6 months) comes to my office after referring the newborn hearing screening I complete the following: (check all that apply)

☐ Otoscopy
☐ Case history
☐ 1000 Hz Tympanometry
☐ 226 Hz Tympanometry
☐ Acoustic reflexes
☐ Distortion Product Otoacoustic Emissions
☐ Transient Evoked Otoacoustic Emissions
☐ Click ABR
☐ Tone burst ABR
☐ Chirp ABR
☐ Bone conduction ABR
☐ Chirp ASSR
☐ Tone burst ASSR
☐ Behavioral Observation
☐ Visual Reinforcement Audiometry
☐ Other (list in comments section below)

Comment: _____

For natural sleep or sedated electrophysiological testing on a new patient (with no previous testing completed), which test stimulus do you start with when testing air-conduction thresholds?

○ Click ABR
○ 250 Hz tone burst ABR
○ 500 Hz tone burst ABR
○ 1000 Hz tone burst ABR
○ 2000 Hz tone burst ABR
○ 4000 Hz tone burst ABR
○ 250 Hz Chirp ABR
○ 500 Hz Chirp ABR
○ 1000 Hz Chirp ABR
○ 2000 Hz Chirp ABR
○ 4000 Hz Chirp ABR
○ Chirp ASSR
○ Tone burst ASSR
○ Other (list in comment section)

Comment: _____

If an infant (6-12 months) comes to my office after referring the newborn hearing screening I complete the following: (check all that apply)

- ☐ Otoscopy
- ☐ Case history
- ☐ 1000 Hz Tympanometry
- ☐ 226 Hz Tympanometry
- ☐ Acoustic reflexes
- ☐ Distortion Product Otoacoustic Emissions
- ☐ Transient Evoked Otoacoustic Emissions
- ☐ Click ABR
- ☐ Tone burst ABR
- ☐ Chirp ABR
- ☐ Bone conduction ABR
- ☐ Chirp ASSR
- ☐ Tone burst ASSR
- ☐ Behavioral Observation
- ☐ Visual Reinforcement Audiometry
- ☐ Other (list in comments section below)

Comment: _____

When measuring a child's hearing thresholds via ABR/ASSR methods, I use the following audiometric transducer most of the time:

- ○ Insert earphones
- ○ Standard or supra-aural headphones

Comment: _____

If an infant comes to my office after referring the newborn hearing screening in one ear and passing in the other, I complete testing in:

- ○ Only the ear that referred the screening
- ○ Both ears

Comment: _____

If an infant comes to my office after referring the newborn hearing screening in one ear and passing in the other, I complete testing in this order:

- ○ In the referred ear first followed by the passed ear
- ○ In the passed ear first followed by the referred ear

Does your facility routinely provide re-screening of infants who refer on the newborn hearing screening for both their initial and repeat screening at their birthing hospital?

- ○ Yes
- ○ No
- ○ Unsure

Comment: _____

Does your facility have a limited protocol (ie. Tymps, OAEs, and/or Click ABR only) for otherwise well babies with no risk factors who refer on the newborn hearing screening at their birth hospital?

- ○ Yes we complete limited testing (tymps, OAEs and/or click ABR only)
- ○ No we complete a full diagnostic evaluation
- ○ Unsure

Comment: _____

My facility has a separate diagnostic protocol for babies who are referred from well-baby nurseries vs NICU babies admitted for greater than 5 days.

- ○ Yes
- ○ No
- ○ Unsure

Comment: _____

If an infant/young child has a confirmed hearing loss I refer to the following professionals: (select all that apply)

- ☐ ENT for medical clearance
- ☐ PCP for medical clearance
- ☐ State early intervention program for services
- ☐ Audiologist for amplification
- ☐ Private speech-pathologist for evaluation
- ☐ Other (please specify)

Comment: _____

At your facility what risk factors require additional follow up testing? Select all that apply

- ☐ Ototoxic medication
- ☐ Meningitis
- ☐ Family history of hearing loss
- ☐ Intrauterine infections (including CMV, rubella, and herpes simplex virus)
- ☐ Prematurity
- ☐ Maternal diabetes
- ☐ Anoxia
- ☐ Malformations of the ear, nose or throat
- ☐ Apgar score from 0-3
- ☐ Low birth weight
- ☐ Hyperbilirubinemia
- ☐ Prolonged mechanical ventilation and/or severe respiratory distress
- ☐ Intensive care stay greater than 5 days
- ☐ Other (please specify)

Comment: _____

How many days until your next available natural sleep ABR?

- ○ 0-5 days
- ○ 6-10 days
- ○ 11-15 days
- ○ 15+ days (please specify if over 15 days in comment section)
- ○ unsure

Comment: _____

How many days until your next available sedated ABR?

- ○ 0-10 days
- ○ 11-20 days
- ○ 21-30 days
- ○ 30+ days (please specify if over 30 days in comment section)
- ○ unsure

Comment: _____

Out of the following factors, please select the top three reasons as to why it may be difficult to complete ABR testing within one appointment:

- ☐ Patient sleep state/waking up
- ☐ Electrical noise interference
- ☐ Appointment time too short
- ☐ Equipment issues
- ☐ Parent request to discontinue testing

Other/Comment: _____

During the past six months approximately what percentage of natural sleep ABRs could not be completed due to the infant sleep state/waking up?

- ○ 0-25%
- ○ 25-50%
- ○ 50-75%
- ○ 75-100%

During the past six months approximately what percentage of natural sleep ABRs could not be completed due to electrical noise/interference?

- ○ 0-25%
- ○ 25-50%
- ○ 50-75%
- ○ 75-100%

During the past six months approximately what percentage of natural sleep ABRs could not be completed due to not enough time in the appointment?

- ○ 0-25%
- ○ 25-50%
- ○ 50-75%
- ○ 75-100%

During the past six months approximately what percentage of natural sleep ABRs could not be completed due to equipment issues?

- ○ 0-25%
- ○ 25-50%
- ○ 50-75%
- ○ 75-100%

During the past six months approximately what percentage of natural sleep ABRs could not be completed due to parental request to discontinue testing?

○ 0-25%
○ 25-50%
○ 50-75%
○ 75-100%

Which of the following instructions do you provide to families prior to a natural sleep ABR appointment? (select all that apply)

☐ Bring infant sleep deprived
☐ Bring infant hungry
☐ Bring items that comfort the infants (bottle, blanket, pacifier, etc.)
☐ Bring the babies car seat for them to sleep in for testing.
☐ Do not put lotion on the infant's face
☐ Bring an additional adult to help keep the infant awake during the car ride
☐ Bring an additional adult if planning on bringing additional children (older siblings) to the appointment.
☐ Other (please specify)
☐ Our facility provides no instructions prior to the appointment

Other/Comment:

_____

How do you provide families with instructions prior to a natural sleep ABR? (select all that apply)

☐ Over the phone when they schedule the appointment
☐ Over the phone via a confirmation call a few days before/or day before appointment
☐ A letter in the mail prior to the appointment
☐ I do not provide families with instructions

Behavioral Testing

Currently what is the length of appointment you have to complete an outpatient behavioral appointment for a child 6-36 months?

- ○ 30 minutes
- ○ 45 minutes
- ○ 60 minutes
- ○ 90 minutes
- ○ Other (include length in comment section)

Comment: _____

When measuring a child's hearing thresholds who is 6-12 months of age, I use the following audiometric transducer most of the time

- ○ Insert earphones
- ○ Standard or supra-aural headphones
- ○ Soundfield with loudspeakers/reinforcers at 0 degrees azimuth
- ○ Soundfield with loudspeakers/reinforcers at 45 degrees azimuth
- ○ Soundfield with loudspeakers/reinforcers at 90 degrees azimuth

Other/Comment: _____

When measuring a child's hearing thresholds who is 12-36 months of age, I use the following audiometric transducer most of the time

- ○ Insert earphones
- ○ Standard or supra-aural headphones
- ○ Soundfield with loudspeakers/reinforcers at 0 degrees azimuth
- ○ Soundfield with loudspeakers/reinforcers at 45 degrees azimuth
- ○ Soundfield with loudspeakers/reinforcers at 90 degrees azimuth

Other/Comment: _____

For VRA testing what is your preferred position of patient?

- ○ In a high chair
- ○ On a caregiver's lap

Other/Comment: _____

Do you routinely use a high chair?

- ○ Yes
- ○ No

Comment: _____

Do you routinely use a test assist?

- ○ Yes
- ○ No

Comment: _____

What stimulus type do you routinely use? (select all that apply)

- ☐ Pure tones
- ☐ Warbled tone
- ☐ Narrowband noise
- ☐ Pediatric noise/FRESH noise
- ☐ Other (please specify)

Comment: _____

For VRA testing on a new patient (with no previous testing completed), which test stimulus do you start with when testing air-conduction thresholds?

- ○ Speech
- ○ Frequency specific stimuli (warble tones or noise)
- ○ Other (comments)

Comment: _____

At what frequency do you typically begin conditioning? (select one)

○ 250 Hz
○ 500 Hz
○ 1000 Hz
○ 2000 Hz
○ 4000 Hz
○ 8000 Hz
○ Other (please specify)

Comment: _____

What do you consider a normal VRA response? (select all that apply)

☐ 45 degree head turn
☐ 90 degree head turn
☐ eye shift
☐ look up
☐ other (please specify)

Other/Comment: _____

Do you use bone conduction for VRA testing?

○ Yes
○ No

Comment: _____

What are the top three pitfalls of VRA testing?

☐ Inadequate setup precluding the consistent judgement of head turns
☐ Inadequate communication between tester and test assist
☐ Attempting to condition with sub-threshold stimuli
☐ Not establishing clear responses at supra-threshold levels before descending to threshold
☐ Incorrect scoring due to false positive responses
☐ Rhythmical phasing that gives response clues to patient
☐ Use of toys/distractors that provides too little or too much engagement for the child
☐ Other (please specify)

Comment: _____

Do you have a lower limit stop criteria for testing threshold in children 6-36 months of age (ie. Do you not test below a certain intensity level)?

○ Yes
○ No

If you have a lower limit stop criteria for testing children 6-36 months what is the lowest level you stop at?

○ 20
○ 15
○ 10
○ 5
○ 0
○ Other

Do you consider the responses you record to be a minimal response level (MRL) or threshold?

○ MRL
○ Threshold
○ Other (please specify)

Comment: _____

What is considered a normal hearing threshold or MRL for an infant 6-36 months of age?

○ 15 dB HL or better
○ 20 dB HL or better
○ 25 dB HL or better
○ Other (please specify)

Comment: _____

What are some factors that can potentially impact the reliability of the test results?

☐ State of alertness
☐ Patient attention
☐ Parental interference
☐ Presence of developmental/cognitive delay
☐ Other (Please specify)

Comment:

_____

Demographics

Current state where you practice (select one):

- ○ Alabama
- ○ Alaska
- ○ Arizona
- ○ Arkansas
- ○ California
- ○ Colorado
- ○ Connecticut
- ○ Delaware
- ○ Florida
- ○ Georgia
- ○ Hawaii
- ○ Idaho
- ○ Illinois
- ○ Indiana
- ○ Iowa
- ○ Kansas
- ○ Kentucky
- ○ Louisiana
- ○ Maine
- ○ Maryland
- ○ Massachusetts
- ○ Michigan
- ○ Minnesota
- ○ Mississippi
- ○ Missouri
- ○ Montana
- ○ Nebraska
- ○ Nevada
- ○ New Hampshire
- ○ New Jersey
- ○ New Mexico
- ○ New York
- ○ North Carolina
- ○ North Dakota
- ○ Ohio
- ○ Oklahoma
- ○ Oregon
- ○ Pennsylvania
- ○ Rhode Island
- ○ South Carolina
- ○ South Dakota
- ○ Tennessee
- ○ Texas
- ○ Utah
- ○ Vermont
- ○ Virginia
- ○ Washington
- ○ West Virginia
- ○ Wisconsin
- ○ Wyoming

Current degree designation (please select most recent degree completed)

- ○ AuD
- ○ Master Degree
- ○ PhD
- ○ Other (please specify)

What is your gender?

- ○ Female
- ○ Male
- ○ Non-binary
- ○ Do not wish to respond

Are you now employed

○ full time
○ part time
○ not employed
○ retired
○ other (please specify)

Comment:

_____

State the number of years you have been working as an audiologist:

○ 1-5 years
○ 6-10 years
○ 11-15 years
○ 16-20 years
○ +20 years

Of your number of years of experience, State the number of years you have been routinely seeing children:

○ 1-5 years
○ 6-10 years
○ 11-15 years
○ 16-20 years
○ +20 years

Please choose the best terms to describe your current pediatric audiology work setting:

○ private practice- owner
○ private practice- employee
○ hospital
○ college/university
○ ENT office
○ department/warehouse store
○ school
○ other (please specify)

Comment:

_____

How many audiologists in your facility/practice see children routinely?

○ 1-3
○ 4-7
○ 8-10
○ Over 10

What is the average number of diagnostic evaluations your facility performs each month for children age birth-6 months?

○ 0-5
○ 6-10
○ 11-15
○ 16+
○ unsure

What is the average number of diagnostic evaluations your facility performs each month for children age 7 months to 2.11 years?

○ 0-5
○ 6-10
○ 11-15
○ 16+
○ unsure

What is the average number of diagnostic evaluations your facility performs each month for children age 3-5 years?

○ 0-5
○ 6-10
○ 11-15
○ 16+
○ unsure