

Hearing Screening in North Carolina's NICU and Well-Baby Nurseries: Impact of JCIH 2019 and COVID-19

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Abstract

Purpose: Over an 18-month period in 2020–2021, the North Carolina Early Hearing Detection and Intervention (EHDI) program in collaboration with the North Carolina Leadership Education in Neurodevelopmental and Related Disabilities (LEND) program conducted a statewide examination of newborn hearing screening practices in North Carolina's 24 Neonatal Intensive Care Units (NICU) and 86 well-baby nurseries to determine how current protocols and procedures conform to those recommended by the Joint Committee on Infant Hearing (JCIH) in its Year 2019 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs. The COVID-19 pandemic emerged during the study period and motivated a second aim, to examine the impact of the pandemic on infant hearing screening.

Results: Our findings revealed that the hospitals in North Carolina are fully committed to their hearing screening programs as demonstrated by a 100% response rate and numerous strengths in both the NICU and well-baby nurseries. Even so, for many hospitals we identified opportunities for program development or improvement based on JCIH 2019 recommendations, especially those concerning oversight of the screening program by a pediatric audiologist, direct referral to an audiologist for NICU babies who fail the in-hospital screening, and audiology referral for well babies who fail the outpatient rescreen. Following the investigation, the NC-EHDI program has worked in partnership with hospitals to provide information, technical assistance, and resources based on our findings and recommendations. The authors would be happy to share the survey instruments and other resources developed for this project with EHDI programs in other states interested in conducting a similar study.

Keywords: Hearing Screening, JCIH 2019, COVID-19, NICU, Well-Baby, Infant

Acronyms: AABR = automated auditory brainstem response; ANSD = auditory neuropathy spectrum disorder; cCMV = congenital cytomegalovirus; EHDI = Early Hearing Detection and Intervention; LEND = Leadership Education in Neurodevelopmental and Related Disabilities; OAE = otoacoustic emissions

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Permanent hearing loss¹ is the most common condition identified through newborn screening, detectable in 1.7 newborns per 1000 in the general population (CDC, 2019). The prevalence for both cochlear hearing loss and auditory neuropathy spectrum disorder (ANSD) is significantly higher for infants requiring hospitalization in the neonatal intensive care unit (NICU; Berg et al., 2005; Hille et al., 2007; Robertson et al., 2009; White et al., 1994; Xoinis et al.; 2007). Accordingly, practice guidelines published by the Joint Committee on Infant Hearing (JCIH, 2019) recommend separate hearing screening protocols for the NICU and well-baby nurseries.

The JCIH was established in 1969 with representatives from audiology, otolaryngology, pediatrics, and nursing. Today, representatives to the JCIH include 13 organizations, each dedicated to ensuring early identification, intervention, and follow-up care for infants and young children with hearing loss. The Joint Committee's primary activity has been publication of position statements summarizing the status of infant hearing screening along with recommendations for preferred practice in early identification and intervention for newborns and infants with or at risk for hearing loss (CDC, 2021). Over its 50+ year history, the JCIH has published eight position statements. The current clinical practice guideline is the JCIH *Year 2019 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs* (JCIH, 2019).

For hearing screening in the NICU, JCIH 2019 reaffirmed the Joint Committee's previous position statement (JCIH, 2007), which recommended automated auditory brainstem response (AABR) as the sole hearing screening technology for infants admitted to the NICU for more than 5 days. Also reaffirmed for NICU hearing screening was direct referral to an audiologist for rescreening and, if indicated, comprehensive audiological evaluation including diagnostic ABR for infants who fail the in-hospital screen. For hearing screening in the well-baby nursery, the JCIH currently recommends AABR and otoacoustic emissions (OAE) technologies, alone or in combination, and outpatient rescreening for babies who do not pass the in-hospital screen (JCIH, 2019). A notable change in JCIH 2019 is the recommendation regarding follow-up screening of well babies who do not pass an initial AABR. For infants in the well-baby nursery who fail an AABR screening, the previous position statement, JCIH 2007, recommended they *not* be rescreened and passed using OAE technology because of presumed risk for ANSD. Although AABR is still the preferred protocol in JCIH 2019, because of the low incidence of ANSD in the well-baby population and challenges associated with access to outpatient rescreening, JCIH currently advises that rescreening of well-babies may be accomplished using either OAE or

¹The authors recognize the importance of culturally sensitive language when referring to content related to people who are deaf or hard of hearing. Consistent with JCIH 2019, the term *hearing loss* is used here to clearly convey audiological concepts and conditions. Also consistent with JCIH 2019, we use the term *fail* in reference to infants who do not pass their newborn hearing screening.

AABR. These and other JCIH 2019 recommendations pertaining to hearing screening in the NICU and well-baby nurseries are summarized in Table 1.

An overarching theme within JCIH 2019 that applies to both settings is the recommendation for greater audiology oversight of hearing screening programs in all state/territory hearing screening programs, at both the systems level and the individual programs level (Table 2). JCIH 2019 recommends that an audiologist with experience in evaluating newborns and young children be involved in the development and oversight of each component of the hearing screening program, including selection of screening technology based on the population to be screened, with confirmation that equipment calibration performed by the manufacturer is completed in a manner consistent with purported screening parameters. JCIH 2019 also advises hospitals and agencies to designate a physician/provider to oversee the medical aspects of the EHDI program.

For decades, the practice guidelines published by JCIH have impacted hearing screening protocols throughout the United States and beyond. North Carolina's Early Hearing Detection and Intervention (NC-EHDI) Program was established in 2000, following a legislative mandate in 1999 requiring birthing hospitals to provide physiologic screening for hearing loss prior to discharge (Fort, 2017). Soon after the establishment of NC-EHDI, a group of stakeholders from across the state formed an advisory committee to guide the implementation, development, and coordination of EHDI services. Although initially focused on the implementation of newborn hearing screening, NC-EHDI and its advisory committee soon expanded its scope to include a variety of issues related to early identification, diagnosis, and intervention services for children with permanent hearing loss. NC-EHDI is now divided into 10 regions of the state, each served by one or more regional consultants.

For purposes of program evaluation and improvement, initially the primary aim of this study was to examine the current status of newborn hearing screening programs in the state's 24 Level III and Level IV NICUs and 86 well-baby nurseries to determine how current protocols and procedures conform to those recommended by JCIH 2019. The COVID-19 pandemic emerged during the NICU study period and motivated a second aim, to examine how the pandemic was impacting infant hearing screening in both the NICU and well-baby nurseries.

Method

Data collection over an 18-month period involved collaboration between the NC-EHDI program and the North Carolina LEND (Leadership Education in Neurodevelopmental and Related Disabilities) Program. LEND is a federally funded, interdisciplinary program that provides graduate-level training, technical assistance, continuing education, and consultation to states regarding screening, diagnosis, advocacy, and treatment for neurodevelopmental and related conditions (HRSA, 2021). Eight LEND audiology trainees from the University

Table 1*JCIH 2019 Recommendations for Hearing Screening in the NICU and Well-baby Nurseries*

Summary of JCIH 2019 Newborn Hearing Screening Recommendations	
Well-Baby	NICU
Interpretive Criteria <ul style="list-style-type: none"> Criteria for hearing screening outcomes should demonstrate both sensitivity and specificity due to the prevalence of hearing loss in infants, manufacturer-reported test performance, and the goal of identifying elevated hearing thresholds that can affect spoken language development. Screening technology that automates results considering both sensitivity and specificity should be used to optimize consistency among tests. 	
Calibration of hearing screening equipment <ul style="list-style-type: none"> Due to a lack of universal standard, calibration should be performed based on manufacturer specifications. 	
Timing of newborn hearing screening <ul style="list-style-type: none"> Infants should have their hearing screened as close to discharge as is feasible. However, there should be ample time to perform a repeat screen should the infant not pass the first screen. If an infant fails the initial screen, the second screening should be performed at least several hours after the first screen. Infants that present with congenital aural atresia in one or both ears or with visible pinna/ear canal deformity such as stenosis or severe malformation should not be screened in either ear but should be referred for diagnostic audiologic evaluation immediately upon discharge. 	Timing of newborn hearing screening <ul style="list-style-type: none"> Although infants can be tested while in the NICU, it is not always feasible for these children to be tested prior to 1 month of age. In these situations, arrangements should be made to test the infant as soon as medically possible.
Screening protocols in the well-baby nursery <ul style="list-style-type: none"> An acceptable pass result consists of a pass result for both ears in a single screening session using either technology prior to hospital discharge. Due to the low incidence of auditory neuropathy in the well-baby nursery, initial screening as well as any repeat screening (second in-hospital screen) can be performed with either OAE or AABR technology. However, the recommendation to rescreen using only AABR technology for infants who fail their initial screen performed with AABR technology is the Committee's preferred recommendation. Rescreening with OAE after a failed initial screen using AABR is acceptable, though an infant with auditory neuropathy in the well-baby nursery will be missed. 	Screening protocols in NICU nursery <ul style="list-style-type: none"> Due to increased rates of hearing loss and auditory neuropathy in this population, screening should solely be performed using AABR. Although not recommended at this time it was noted that screening with both AABR and OAE can aid in preventing infants with mild-moderate hearing loss from being missed. If rescreening is necessary, patient should be referred directly to an audiologist for a comprehensive audiologic evaluation.
Communication and documentation of results <ul style="list-style-type: none"> Families should be informed in such a way that is comforting to the family while still emphasizing the importance of follow-up. It is recommended that this be done using the scripts composed by the National Center for Hearing Assessment and Management (NCHAM) or the state EDHI program. To aid in preventing loss to follow up, results (including the method of testing) should be given to the infant's medical home. 	
Rescreening in the outpatient setting <ul style="list-style-type: none"> For well-infants, a single rescreening of both ears within the same session should be conducted within 1 month of age, or as soon as possible after discharge from the hospital. If the infant does not pass the rescreening, in either ear, the child should immediately be referred to a pediatric audiologist for diagnostic ABR testing. If the rescreening was performed by a pediatric audiologist, a diagnostic evaluation should be conducted within the same appointment. 	
Rescreening in the medical home <ul style="list-style-type: none"> Screenings conducted within the medical home should be limited to a rescreening, as initial screenings should be completed at the infant's birthing center. Rescreening should be conducted in a quiet environment by a trained professional using approved manufacturer calibrated equipment (OAE/ABR). Rescreening should be performed on both ears in the same session regardless of initial screening results. 	
Improving EHDI loss-to-follow-up/loss-to-documentation rates <ul style="list-style-type: none"> States should not only offer newborn hearing screening to all out-of-hospital births, but also be prepared to share results with neighboring states when necessary. When a child is transferred to a different hospital, appropriate documentation should be sent to the receiving hospital specifying if screening has been performed. In cases where the infant is discharged prior to screening an outpatient screening should be scheduled as soon as possible. 	

Note. JCIH = Joint Committee on Infant Hearing; EHDI = early hearing detection and intervention; AABR = automated auditory brainstem response; OAE = otoacoustic emissions.

Table 2

Summary of Joint Committee on Infant Hearing (JCIH) 2019 Recommendations Regarding the Role of the Audiologist in Newborn Hearing Screening Programs

Systems Level Audiology Oversight

- Periodic on-site and/or remote surveillance of individual hospital programs
- Oversight and participation in writing policies and procedures
- Monitoring of program statistics
- Development of referral pathways and timelines with community resources and the state Early Hearing Detection and Intervention (EHDI) program

Hospital Level Audiology Oversight

- Selection of screening technology
- Confirmation of equipment calibration
- Protocols for training and certifying competence of screeners
- Development of policies, procedures, and protocols
- Quality assurance procedures; program staffing requirements and relevant assignments of staff/team members
- Procedures for discharge or transfer plans; assurance of, “acceptable, independent, on-site oversight by an audiologist who is either employed by the hospital or is otherwise independent of the contracted entity in screening programs where services are contracted through an outside entity” (JCIH, 2019 p. 5-7).

of North Carolina’s Doctor of Audiology (AuD) program and their faculty advisors worked with NC-EHDI staff and regional consultants to identify an appropriate individual from each hospital. Prospective participants were contacted by email or by phone in advance to confirm their participation. The LEND trainees also assisted with survey development, correspondence with NC-EHDI staff, data analysis, preparation of hospital reports, and manuscript preparation. Our goal was to recruit the participation of every NICU and well-baby nursery in the state. Some of the hospitals responded immediately, others within a few days. If there was no response after approximately two weeks, an email reminder was sent. If there was still no reply, a phone inquiry was made, and, in a few cases, the study team enlisted the assistance of the NC-EHDI regional consultant.

NICU

In February 2020, a 25-item survey was pilot tested with personnel from two hospitals and distributed electronically to a representative from each of the 24 hospitals in North Carolina with a Level III or Level IV NICU using Qualtrics, a web-based survey tool (Qualtrics, Provo, Ut). Level III and IV NICUs were targeted because they care for the most critically ill newborns and those at highest risk for permanent hearing loss. Level III and IV NICUs provide care for babies born prematurely or with low birth weight, including those with critical illness or conditions requiring sustained life support. They also provide advanced imaging and a full range of respiratory support. Level IV NICUs care for the most complex and critically ill newborns including those requiring medical and surgical specialists (American Academy of Pediatrics, 2012).

The NICU survey included questions regarding screening personnel, technologies used for hearing screening, and protocols for referral and follow-up. It also included questions related to training and continuing education for

screeners as well as challenges associated with hearing screening in the NICU. Additionally, the role of audiology in oversight of the hearing screening program was investigated, as was the impact of COVID-19. The hospital representatives (chosen based on recommendations from NC-EHDI regional consultants) included nurses, nurse managers, administrators, and audiologists. Because the COVID-19 pandemic began during the NICU study period and was not part of the initial survey, a follow-up study was conducted in January 2021, to investigate how the pandemic was impacting hearing screening in the NICU. The COVID-19 follow-up survey asked NICU representatives if the pandemic had affected newborn hearing screening and if so, to describe the effects.

Well-Baby Nurseries

One year following distribution of the NICU survey a second phase of the project addressed North Carolina’s 86 well-baby nurseries. In February 2021, following pilot testing in two hospitals, a 32-item Qualtrics (Provo, Ut) survey was distributed to all 86 birthing hospitals in North Carolina and again directed to an individual recommended by the hospital’s NC-EHDI regional consultant. As with the NICU survey the participation of each hospital representative was confirmed prior to distribution. Because the COVID-19 pandemic was known to be impacting hearing screening in the well-baby nurseries, the survey included two parts. Part 1 consisted of 21 questions pertaining to hearing screening prior to the onset of the pandemic, and Part 2 included 11 questions related to the impact of COVID-19 on well-baby hearing screening. Survey questions for the well-baby nurseries included screening personnel, screening technologies, and protocols for referral and follow-up. Also included were questions related to training and continuing education for screeners as well as challenges associated with hearing screening. In addition, hospitals were asked if there was a protocol for referral of infants with aural atresia or other visible outer

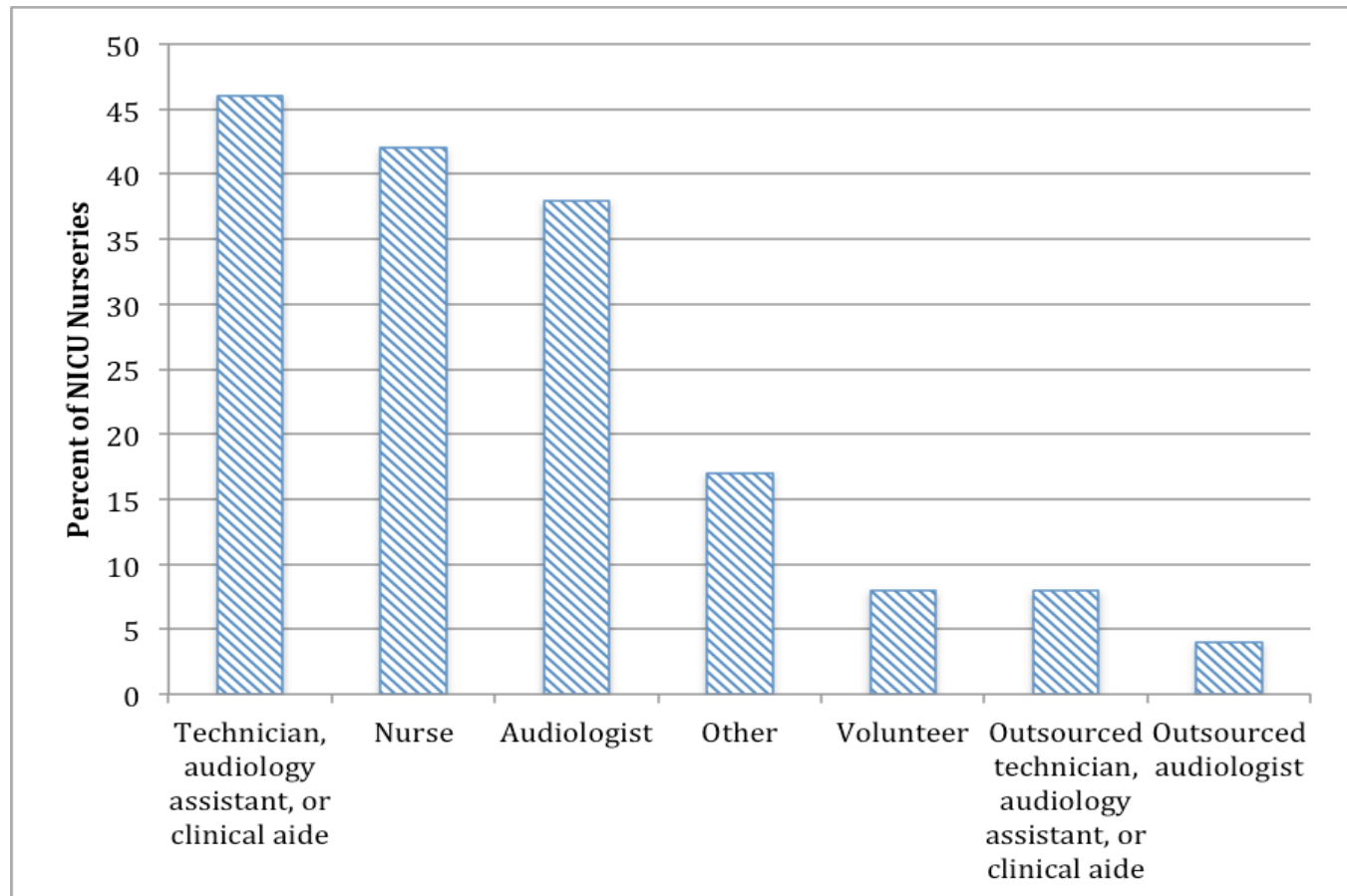
ear anomalies, and they were asked if they were currently providing or planning to conduct screening for congenital cytomegalovirus (cCMV). As with the NICU survey, hospital representatives were also asked if an audiologist provided oversight of the hearing-screening program.

Results

The results of this investigation confirmed that North Carolina's hospitals are fully committed to their hearing screening programs. The information we requested was reported promptly and thoroughly with a 100% response rate for all 24 NICUs and all 86 well-baby nurseries.

Figure 1

Personnel Responsible for Conducting Hearing Screening in the NICU



Note. The total exceeds 100% because respondents could select more than one option.

NICU Nurseries

Screening Personnel

A hospital technician or assistant employed by the institution is most likely to administer the in-hospital screening (Figure 1).

Screening Technology

All 24 NICUs reported using AABR; however, two hospitals reported combined use of AABR and OAE. None of the NICUs reported using OAE only.

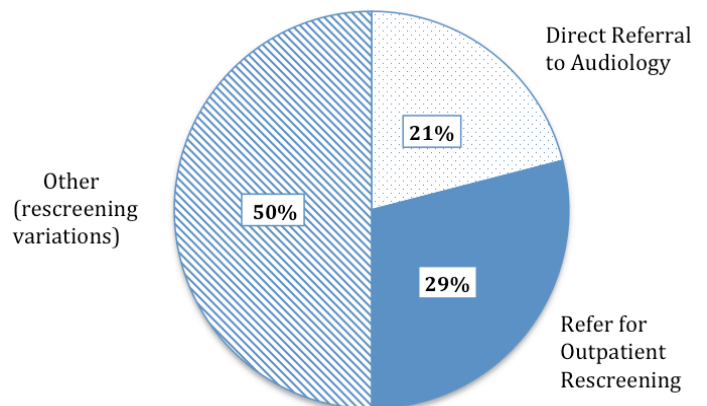
Referral and Follow-up

For the 24 NICUs, five (21%) reported direct referral to an audiologist for babies who fail the hearing screening; seven (29%) reported referral for outpatient rescreening; and 12 (50%) reported a variety of other referral strategies (Figure 2).

For infants *readmitted* to the NICU with a condition or treatment associated with a risk factor for hearing loss, one NICU reported that all infants are rescreened prior

Figure 2

Referral of NICU Infants who Fail the Inpatient Hearing Screening



to discharge, and 15 (63%) reported that infants may be rescreened prior to discharge based on certain conditions such as exposure to ototoxic medications, newly identified

risk factors, previous screening results, or physician orders. Survey respondents for the remaining eight (33%) were not aware of a rescreening protocol for readmitted infants.

Training and Continuing Education for Screeners

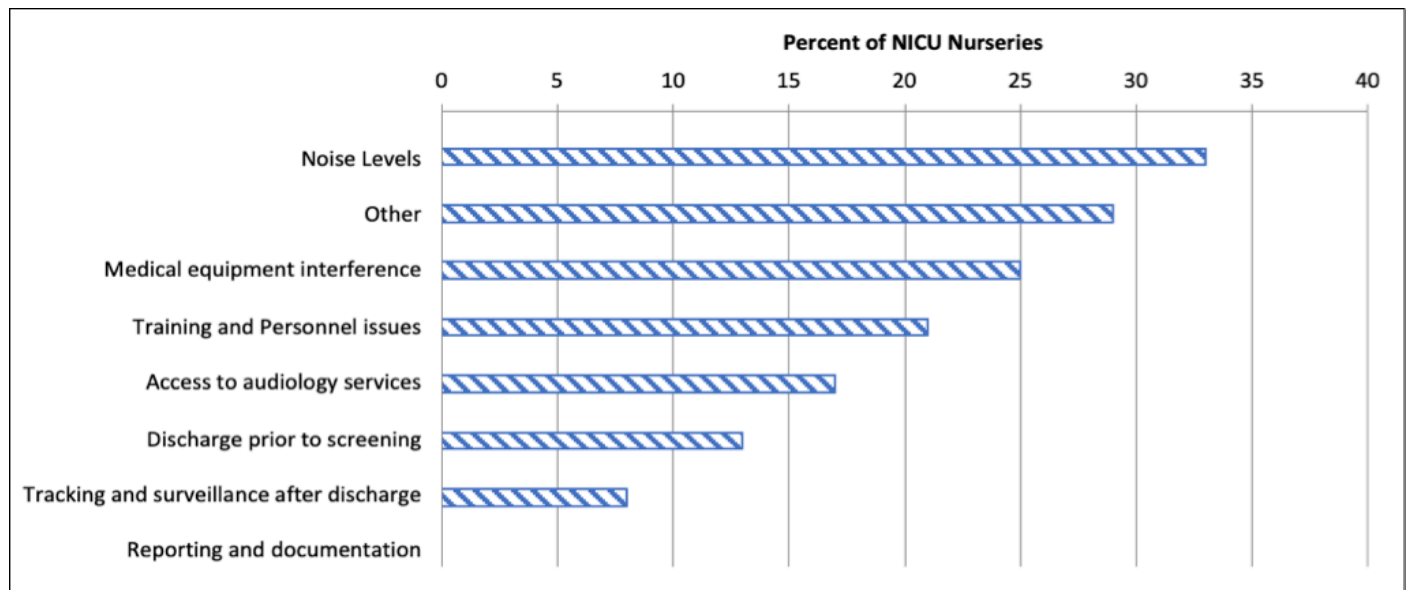
The frequency of training and continuing education among the 24 NICUs varied considerably. Eight hospitals (33%) reported 1 to 2 times per year and 13 (54%) reported no regular continuing education. The remaining three employed audiologists and/

or contracted providers whose continuing education requirements are unknown.

Challenges

Challenges associated with hearing screening in the NICU, summarized in Figure 3, included a variety of issues such as noise levels, medical equipment interference, training and personnel issues, limited access to audiology services, discharge prior to screening, and tracking/surveillance after discharge. None of the NICUs reported challenges related to reporting and documentation.

Figure 3
Challenges Associated with Hearing Screening in the NICU



Note. The total exceeds 100% because respondents could select more than one option.

Audiology Oversight

Sixteen NICUs (67%) reported direct oversight of the screening program by an audiologist.

COVID-19

The COVID-19 pandemic had not emerged when the planning began for the NICU project in the fall of 2019. Because of the potential impact of the pandemic on hearing screening in the NICU, a follow-up survey was conducted in November 2020. Responses from all 24 NICUs indicated that COVID-19 did not appreciably affect hearing screening in the NICU other than a few hospitals that noted a change in screening location for babies requiring a second in-hospital screen, or a delay in screening if the baby had been exposed to COVID-19 or was awaiting test results. One hospital reported that babies with COVID-19 positive mothers were required to wait 30-45 days before a hearing screening could be provided.

Well-Baby Nurseries

Screening Personnel

A nurse or hospital technician was most likely to administer the in-hospital screening (Figure 4) and a nurse or pediatrician was most likely to provide screening results

to families and discuss recommendations for babies who failed the in-hospital screening (Figure 5). Hospital technicians, certified nursing assistants, administrative support staff, and audiologists were other providers who discussed screening results with families.

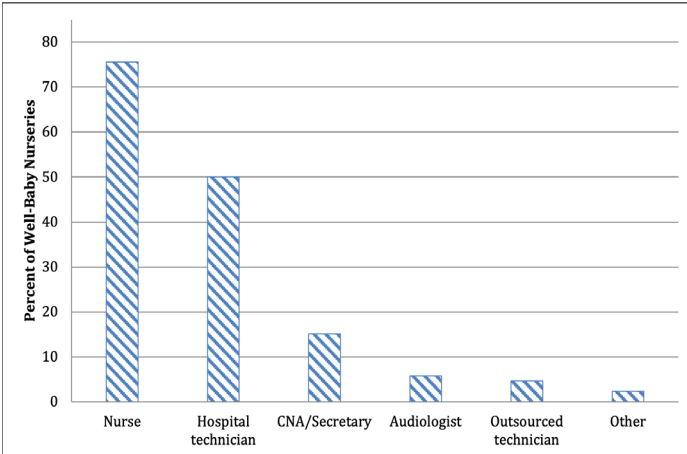
Screening Technology

As summarized in Table 3, for the in-hospital screening, 76 (88%) of the well-baby nurseries reported using AABR only and five (6%) reported using OAE only. For infants requiring outpatient rescreening, 61 (71%) reported AABR and 10 (12%) reported OAEs. A few hospitals reported a combination of screening technologies or stated that outpatient rescreening was not conducted at their birthing hospital.

Referral and Follow-up

As summarized in Figure 6, 51 well-baby nurseries (60%) reported direct referral to an audiologist following a failed outpatient rescreening; 20 (23%) reported referral to a pediatrician or other primary care provider; and seven (8%) reported referral to an ear nose and throat physician. The remaining eight nurseries (9%) reported some other protocol for referral of babies who fail the outpatient rescreen.

Figure 4
Personnel Responsible for Conducting Newborn Hearing Screening in the Well-Baby Nursery



Note. The total exceeds 100% because respondents could select more than one option.

Table 3
Screening Technology Used in the Well-baby Nursery for Initial In-Hospital Screening and Outpatient Rescreens for Infants who Fail the In-Hospital Screen

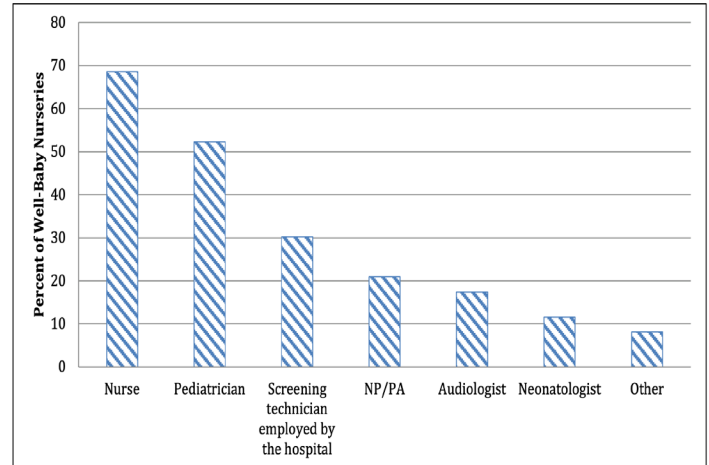
	In-Hospital Screen	Outpatient Rescreen
Auditory Brainstem Response (ABR) only	76 (88%)	61 (71%)
Otoacoustic emissions (OAE) only	5 (6%)	10 (12%)
OAE or ABR	3 (3%)	1 (1%)
OAE followed by ABR	9 (10%)	0
ABR followed by OAE	0	2 (2%)
Not applicable	1 (1%)	12 (14%)

Note. The total exceeds 100% because respondents could select more than one option.

Training and Continuing Education for Screeners

Most well-baby nurseries (56%) reported annual continuing education; however, nearly half (43%) reported no regular continuing education for screening personnel. Of those reporting regular training, in-person was the most common method followed by online modules, electronic materials, and competency exams.

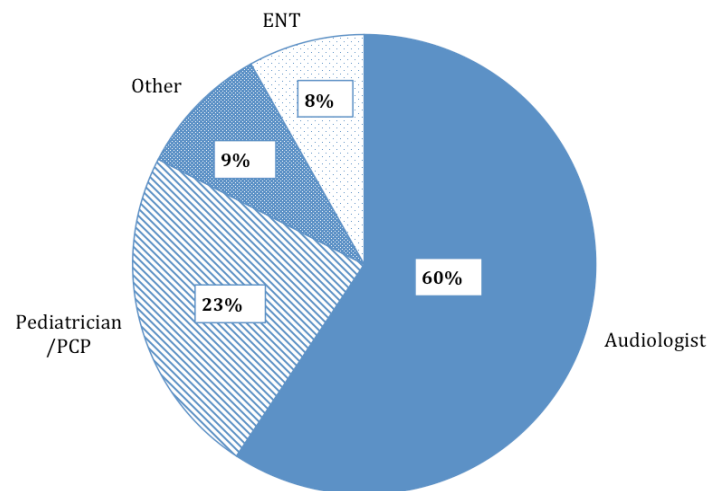
Figure 5
Personnel Responsible for Informing the Family of In-Hospital Screening Results for the Well-Baby Nurseries



Note. The total exceeds 100% because respondents could select more than one option.

NP/PA = Nurse Practitioner/Physician's Assistant.

Figure 6
Referral of Well Babies who Fail the Outpatient Rescreen



Note. ENT = ear, nose, and throat doctor; PCP = primary care physician.

Challenges

Nearly all well-baby nurseries reported challenges associated with hearing screening. The most frequently cited challenges were associated with equipment issues and tracking following discharge. A number of other challenges were also noted (see Figure 7).

CMV Screening

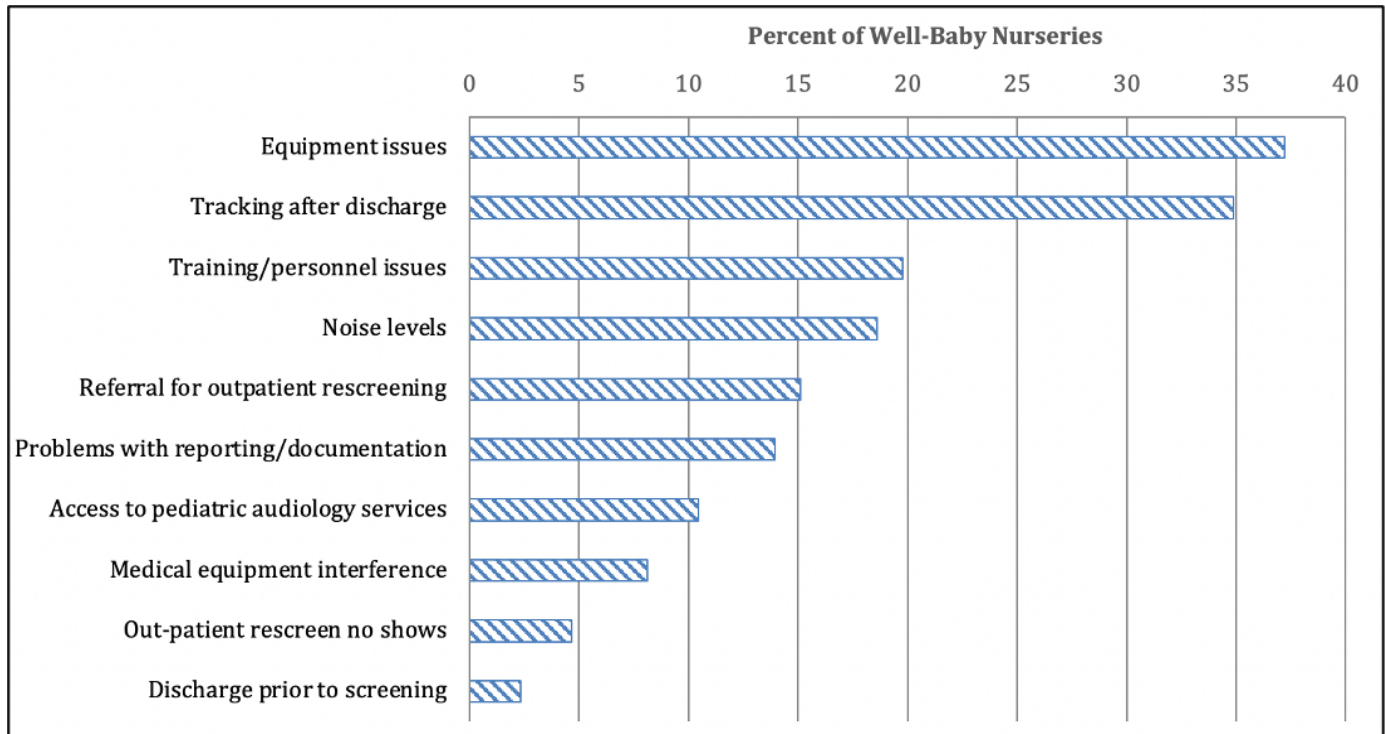
Eleven (13%) well-baby nurseries reported screening for CMV during the study period and seven (8%) indicated they were planning to implement CMV screening in the future.

Aural Atresia

Twenty-seven (13%) well-baby nurseries reported a formal protocol for infants born with aural atresia and other visible ear anomalies. Protocols included referral to an

Figure 7

Challenges Reported by Well-Baby Nurseries Prior to Onset of the COVID-19 Pandemic



Note. The total exceeds 100% because respondents could select more than one option.

audiologist, pediatrician, or ENT regardless of screening outcome. Fifty-nine (69%) reported not having a formal protocol for referral of infants with aural atresia or other visible ear anomalies.

Audiology Oversight

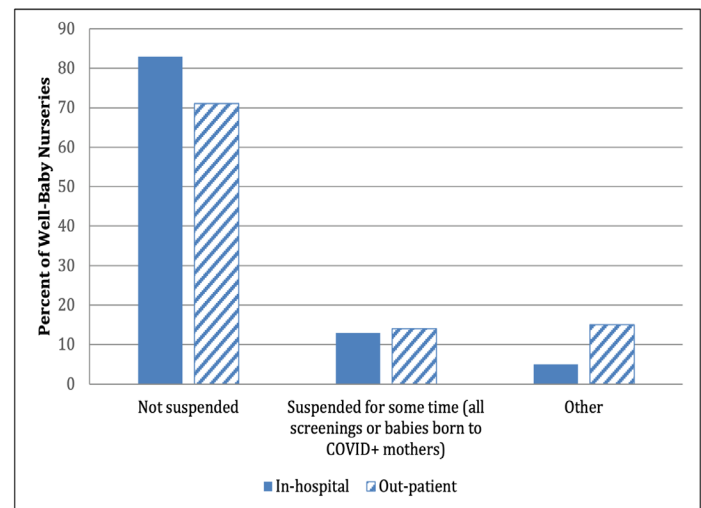
Twenty-six (30%) well-baby nurseries reported direct oversight of the screening program by an audiologist.

COVID-19

The COVID-19 pandemic had already emerged at the beginning of the well-baby screening phase of the study and it impacted both in-hospital screening and outpatient rescreening. As summarized in Figure 8, the outcomes clustered into three categories. Seventy-one hospitals (83%) reported no COVID-19 related suspension of in-hospital hearing screening and 61 hospitals (71%) reported no suspension of outpatient rescreening. Temporary suspension of in-hospital hearing screening was reported by 11 hospitals (13%) and by 12 (14%) for outpatient rescreening. The remaining hospitals (Other) reported suspension of initial inpatient hearing screening if the mother was found to be COVID positive. In those cases, an infant was usually scheduled for later outpatient screening. Many well-baby nurseries implemented additional precautions to enable screening of babies with COVID-positive mothers, and some hospitals suspended outpatient screening temporarily but with added protocols to mitigate delays or loss to follow-up.

Figure 8

Impact of the COVID-19 Pandemic on Hearing Screening in the Well-Baby Nurseries



Recommendations to Hospitals

Many strengths, reflected by protocols and procedures consistent with JCIH 2019 recommendations, were noted for all screening programs and for some there were no recommendations for improvement. For many of the NICUs, however, the findings resulted in one or more specific recommendations.

NICU Nurseries

In November 2020, the study team contacted each NICU representative to thank them for their participation and provide two documents: a statewide summary of aggregate findings and an individualized report with recommendations, if any, for each hospital. Recommendations were made for 20 (83%) of the 24 NICUs. The statewide aggregate report included a summary of screening technologies employed; audiology oversight of screening programs; screening personnel; challenges associated with NICU hearing screening; and next steps after a failed in-hospital screening. The individualized reports highlighted areas perceived to be strengths of the program, as well as any recommendations for programmatic modification based on JCIH 2019 recommendations. This information was also provided to the NC-EHDI regional consultant for each hospital and to the NC-EHDI Coordinator. In February 2021, a final report was submitted and presented to the NC-EHDI advisory committee. The study team considered all recommendations to be important but identified three as immediate priorities: (a) babies who do not pass the in-hospital hearing screening should be referred directly to a pediatric audiologist for follow-up, (b) clarification should be sought regarding how a few of the NICUs were using OAEs in conjunction with AABR, and (c) need for confirmation of rescreening for infants readmitted to the NICU or pediatric intensive care unit who are at risk for permanent hearing loss. Recommendations also included greater oversight of the screening program by an audiologist if needed, and more systematic and ongoing continuing education for screening personnel along with suggested resources such as those developed by NCHAM. With submission of the final report, the study team concluded the NICU study. The NC-EHDI regional consultants, each of whom provided the contact person for the 24 NICUs, have since communicated directly with the hospitals in their regions to offer guidance, technical assistance, and resources.

Well-Baby Nurseries

Because of the large number of well-baby nurseries, variability in the contact person/s for some hospitals, and the potential for ongoing changes related to COVID-19, a separate report was not sent to each hospital as was done for the NICUs. Instead, the study team summarized key findings for NC-EHDI and its regional consultants to share with well-baby nurseries in each region. In addition to a summary of overall findings, the report highlighted the following needs for some hospitals based on JCIH 2019 recommendations: (a) direct referral to an audiologist following a failed outpatient rescreening, (b) regular educational in-service training for program personnel, (c) oversight of the program by an audiologist with experience in evaluating newborns and young children, and (d) implementation of a protocol for referring infants with congenital aural atresia or visible pinna/ear canal deformities for audiologic assessment. The report also emphasized the need for ongoing monitoring of potential impacts from the COVID-19 pandemic.

Discussion

The primary aim of this investigation was to assess newborn hearing screening practices in North Carolina's NICU and well-baby nurseries, and to determine how current protocols and procedures compared to those recommended by JCIH 2019. A second aim was to assess the impact of the COVID-19 pandemic on infant hearing screening.

Hearing Screening in the NICU

As expected, NICU hearing screening personnel included a variety of healthcare providers such as hospital-based technician/assistants, nurses, or audiologists. We were also interested in the screening technology employed in our NICUs and found, unsurprisingly, that nearly all NICUs reported using AABR only, with none using OAE as the sole screening technology. However, two NICUs reported using AABR and OAE. Although some NICU infants are not at risk for neural hearing loss, JCIH recommends AABR as the sole hearing screening technology because of its ability to detect ANSD, a condition known to be substantially more prevalent in this population (JCIH, 2007, 2019). This finding provided an opportunity for NC-EHDI consultants to remind NICUs in their regions of this longstanding JCIH recommendation.

An important finding related to NICU screening was that many hospitals were not directly referring to a pediatric audiologist when an infant fails the NICU hearing screening. Because of the high prevalence of sensorineural hearing loss in the NICU population, and the importance of timely diagnosis and intervention, JCIH, in both the 2007 and 2019 position statements, recommends direct referral of infants who fail their NICU hearing screening to an audiologist for rescreening and, if indicated, for a diagnostic ABR evaluation (JCIH, 2007, 2019). Although this requires the infant to be medically stable, direct referral to an audiologist is needed as soon as possible to promote early diagnosis and intervention, which in some cases can begin while the infant is still in the NICU (Grosnik & Baroch, 2020). Sapp et al. (2020) found that hearing screening and diagnostic evaluations are often delayed for NICU infants because of medical factors and lengthy NICU admissions, noting that specific clinical guidelines should be considered for this population to facilitate the timing and delivery of hearing healthcare. Fortunately, a revised protocol resulting in direct referral to an audiologist should be straightforward to implement if NICUs choose to do so. The need for direct referral to an audiologist was cited as a top priority in our report to the NICUs, and according to the NC-EHDI manager, many hospitals that were not following this JCIH recommendation have since modified their referral criteria. On a related topic, although many hospitals reported screening of infants *readmitted* for a condition or treatment associated with a risk factor for hearing loss, some appeared to lack specific protocols. NC-EHDI has also worked with hospitals to address this issue.

Our findings also revealed a perceived need among many NICUs for more systematic training and continuing

education related to hearing screening. Hospitals are required to assume responsibility for ensuring the qualifications of their screening personnel and most appear to be making a deliberate effort to do so. We have observed anecdotally, however, that some hospitals are unaware of training materials available to hearing screeners such as the Newborn Hearing Screening Training Curriculum (NHSTC) developed by NCHAM and recently updated in 2020. The NHSTC is an online interactive competency-based course available at no charge and designed to provide a thorough understanding of the components necessary for conducting quality newborn hearing screening based on JCIH recommendations (NCHAM, 2020).

Regarding challenges encountered with NICU hearing screening, we were surprised by the number and variety of issues. Excessive noise was cited most frequently, but the reported challenges included a range of other issues. The current study did not permit exploration of details associated with these challenges, but the information has been used by NC-EHDI for further inquiry and follow-up.

Hearing Screening in the Well-Baby Nursery

As with the NICUs, personnel consisted of a variety of healthcare providers. More than 80% of the nurseries reported that a hospital technician or nurse provides the screening. Also noted for approximately half of the well-baby nurseries, if a baby does not pass the in-hospital screen, a nurse or pediatrician is the professional most likely to discuss recommendations with the family. Communication with families regarding screening outcomes is known to have a significant effect on follow-up (Pynnonen et al., 2016). JCIH 2019 states that results of hearing screening should be conveyed immediately to the family so that they are aware of the screening outcome and the importance of follow-up when indicated. Also included in the JCIH 2019 position statement are resources and specific recommendations for documentation and communication with families.

Regarding choice of screening technology, most of the well-baby nurseries reported using AABR for in-hospital screening and for outpatient rescreening. Although JCIH 2019 endorses both technologies, AABR has the potential for detecting ANSD and related retrocochlear dysfunction. Also noted in JCIH 2019, however, is evidence of OAE screening having the potential for greater sensitivity to mild hearing losses. Although an ideal protocol might involve both technologies, practical considerations associated with multiple technologies are acknowledged by the Joint Committee. Even so, considering the high prevalence of sensorineural hearing loss in the NICU population and the relatively small number of NICU nurseries compared to well-baby nurseries, a dual screening protocol that includes both OAE and AABR is worthy of consideration.

Training and continuing education for screeners are critical components of any screening program, and for many are ongoing challenges. Still, we were surprised that more than 40% of the hospital representatives reported a need

for more systematic training and continuing education related to hearing screening. As noted earlier in reference to NICU screening, training materials are available from NCHAM and other organizations. NC-EDHI is working with hospitals interested in obtaining additional resources.

Considering the many details associated with hearing screening of newborns (Winston & Roush, 2016) we were not surprised to see that nearly all well-baby nurseries reported specific challenges that included equipment maintenance, tracking and follow-up after hospital discharge, and excessive noise. As with NICU screening, the current study did not permit exploration of details associated with these challenges, but the information has been used by NC-EHDI for inquiry and follow-up.

Approximately 1 in every 6000 babies is born with visible evidence of external ear anomalies, ranging from mild deformities of the pinna to microtia and aural atresia (Brent, 1999). JCIH 2019 recommends that infants with congenital aural atresia in one or both ears, or with visible pinna/ear canal deformities such as stenosis or severe malformation, not be screened in either ear but instead referred for diagnostic audiologic evaluation immediately upon hospital discharge. JCIH 2019 further states that diagnostic audiologic evaluation for these infants may be accomplished while the infant is in the NICU or other inpatient hospital unit. We are confident that hospitals included in this study report these conditions in the baby's birth history and discharge summary but found that fewer than one-third of the nurseries reported having a formal protocol as recommended by JCIH 2019. In addition to the recommendations of JCIH, organizations like *Ear Community* (earcommunity.org) based in Denver, Colorado, provide information and advocacy related to aural atresia and microtia.

Congenital CMV (cCMV) is the leading cause of non-genetic permanent hearing loss in children (Doutre et al, 2016; Rawlinson et al, 2018). As a result, some states are moving toward cCMV screening, especially for newborns who fail their hearing screen. Because cCMV can result in late-onset sensorineural hearing loss (Cannon et al., 2014), JCIH recommends that infants who test positive on a neonatal screen for CMV receive periodic monitoring by an audiologist, with appropriate hearing technology and early intervention if indicated. In this study, only 12 well-baby nurseries (14%) in North Carolina reported screening for CMV during the study period although seven indicated they were considering implementation of CMV screening in the future. We are unable to report details associated with CMV screening in this study; however, a follow-up investigation is currently underway as part of another NC-LEND/NC-EHDI collaboration. Also, NC-EHDI convened a CMV workgroup in 2019 that includes parent advocates, pediatric infectious disease and primary care physicians, audiologists, research and public health stakeholders with a mission to determine collaborative approaches to support the prevention and reduction of CMV infections in women and newborns; to ensure access to care for affected children, and to perform outreach and education on congenital CMV for patients,

providers, and the general public. The ongoing outreach and educational efforts of this workgroup have contributed to more hospitals implementing or considering the implementation of CMV screening.

The Role of Audiology in Newborn Hearing Screening and Follow-up

Among the most significant and potentially consequential recommendations included in JCIH 2019 is greater audiology oversight of hearing screening programs in both the NICU and well-baby nurseries. As summarized in Table 2, audiology oversight is recommended for all state and territory hearing screening programs at both the systems level and at the individual program level. Our findings revealed that only two-thirds (66%) of the NICUs in North Carolina had direct oversight by an audiologist, and fewer than one-third (30%) of the well-baby nurseries reported oversight of the screening program by an audiologist. Anecdotally, we have observed that many of the larger hospitals or healthcare systems that already employ audiologists are more likely to have direct involvement with the screening programs. In North Carolina, few of the well-baby nurseries are in hospitals that employ audiologists, although some may have contractual arrangements with consulting audiologists. The implementation of audiology oversight, if not already provided, has many potential benefits but will require advocacy and additional financial resources. States whose EHDI programs employ audiologists may have the potential to further develop their consulting roles with hospitals, and in some states it may be possible to expand the role of educational audiologists in providing outpatient rescreening and assessments in regions with limited access to comprehensive services (Sapp et al., 2021). As more hospitals become consolidated within health systems there may be cost-efficient opportunities to expand audiology oversight of hearing screening in both the NICU and well-baby nurseries.

COVID-19

Early hearing detection and intervention, like many healthcare practices, has been significantly affected by the COVID-19 pandemic (Yoshinaga-Itano, 2020). In response to concerns raised by clinicians and public health officials, NCHAM has compiled several COVID-19 resources and documents; among them, a statement from the American Academy of Pediatrics (2020) noting that continuation of newborn hearing screening amid COVID-19 “is essential to ensure healthy and appropriate development.” According to the CDC (2020), vertical transmission of COVID-19 is rare between mother and baby, but all providers who encounter the newborn were advised to take infection control measures. AAP furthermore recommended that “healthcare workers should use gowns, gloves, standard procedural masks, and eye protection (face shields or goggles) when providing care for well babies. When this care is provided in the same room as a mother with COVID-19, healthcare workers may opt to use N95 respirators in place of standard procedural masks, if available” (NCHAM, 2021). The pandemic emerged and intensified during the NICU study period and as noted earlier, a decision was made to

include questions related to the impact of the pandemic in the survey of well-baby nurseries, and to add a follow-up NICU survey in January 2021. For the NICUs, we were pleased to find that COVID-19 did not appreciably affect hearing screening in North Carolina other than a few hospitals noting a change in screening location for babies requiring a second in-hospital screen, or a delay in screening if the baby had been exposed to COVID-19 or was awaiting test results. One hospital reported that COVID-positive mothers and babies were required to wait 30 to 45 days for hearing screening. In the well-baby nursery, most hospitals continued to screen babies, both inpatient and outpatient; however, issues associated with COVID-positive mothers were frequently cited as reasons why hospitals had to modify or halt their screening programs. For hospitals electing to screen babies with COVID-positive mothers, special precautions were taken during screening, including use of PPE (personal protective equipment) and other hygienic procedures. Typically, these precautions also involved thorough cleaning of equipment. Most hospitals screened the baby in the mother’s room, although a few conducted screenings in an isolation area. Some hospitals reported waiting to perform the screen until the last day of the infant’s hospital stay or waiting until the end of the day to screen the baby. It is important to emphasize that the impact of the pandemic may vary significantly across the country based on multiple factors. Blaseg et al. (2021) in a retrospective study of how COVID-19 has impacted newborn hearing screening in six western states, reported significant disruptions including decreased rates of screening by one month of age, screening overall, and referral for early intervention services. The authors note that these disruptions may have important long-term consequences that warrant continued investigation of COVID-19 and its impact on newborn hearing screening. At the time of this writing, the Delta and Omicron variants have caused a resurgence of COVID-19 in some regions. Until the pandemic ends, EHDI programs and providers will need to closely monitor and mitigate any impact of COVID-19.

Strengths and Limitations

An important strength of this study was the full participation of birthing hospitals in North Carolina, which resulted in a 100% response rate from all 24 NICUs and all 86 well-baby nurseries. This outcome is a testament to the dedication of our hospital nurseries and to the perseverance of our research team, and it enabled our EHDI program to assess the current status of infant hearing screening and make specific recommendations statewide. Several potential limitations must also be acknowledged. Our findings are based on responses from a single representative from each hospital with no means of checking the accuracy of the information provided. To help mitigate this concern, hospital representatives were chosen based on the recommendations of NC-EHDI regional consultants, all of whom were familiar with screening personnel in their regions. There was also variability in the respondents’ professional disciplines and backgrounds that may have affected their familiarity with some of the technical aspects

of the newborn hearing screening program. To address this concern, the study team and the NC-EHDI regional consultants were available to support hospital personnel if they had questions or needed assistance when completing the survey. Finally, it is important to acknowledge that the NC-EHDI program, as with most state healthcare agencies, can make recommendations to hospitals regarding clinical practice, but it does not have the authority to prescribe policies and procedures.

Summary and Future Directions

The hospitals in North Carolina are fully committed to their hearing screening programs, as demonstrated by numerous strengths in both the NICU and well-baby nurseries. Even so, for many hospitals we identified opportunities for program development or improvement based on JCIH 2019 recommendations. For the NICU nurseries, our recommendations emphasized the importance of direct referral to a pediatric audiologist for babies who do not pass the in-hospital hearing screening. Also highlighted was the importance of rescreening infants readmitted to the NICU or pediatric intensive care unit with a condition or treatment associated with a risk factor for hearing loss. For the well-baby nurseries, our recommendations underscored the importance of direct referral to an audiologist following a failed outpatient rescreening. Also emphasized was the importance of direct referral to an audiologist and otolaryngologist for babies with visible signs of external ear anomalies. For both the NICU and well-baby nurseries, JCIH 2019 recommends systematic and ongoing continuing education for screening personnel and oversight of the screening program by an audiologist with experience in evaluating newborns and young children. Following the completion of these studies, NC-EHDI has worked in partnership with hospitals to provide additional resources and technical assistance. As a result of this collaborative effort, many programmatic improvements have occurred statewide.

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