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Research Article

Expanding the Role of Educational Audiologists After a Failed Newborn Hearing Screening: A Quality Improvement Study

Caitlin Sapp,[a] Jonathan Stirn,[b] Tammy O'Hollearn,[c] and Elizabeth A. Walker[b]

Purpose: Lack of timely and proximal access to diagnostic hearing evaluation using auditory brainstem response (ABR) testing hampers the effectiveness of Early Hearing Detection and Intervention (EHDI) programs in the United States. This study measured the impact of a state-based quality-improvement (QI) project that provided diagnostic ABR equipment and training to educational audiologists distributed throughout Iowa in regional special education centers.
Method: We used de-identified administrative data generated by the state EHDI program to analyze markers of access to early hearing health care for infants in a preproject condition ("Baseline") compared to the implementation of diagnostic ABRs at the regional special education centers ("QI Project").
Results: Our findings revealed that the QI Project was associated with improvements in timeliness of first hearing evaluation, distance traveled for first hearing evaluation, and likelihood of receiving on-guideline audiology care during the first hearing evaluation.
Conclusions: Following the onset of the QI Project, infants and their families had greater access to initial hearing evaluation after failed newborn hearing screening. This improvement could have cascading effects on timeliness of later intervention among those with confirmed permanent childhood hearing loss.

Universal newborn hearing screening has significantly decreased the age of identification for children who are deaf/hard of hearing (D/HH) and improved the timeliness with which they access intervention (Butcher et al., 2019; Watkin & Baldwin, 2011). Since the nationwide implementation of universal screening in the early 2000s, screening rates now reach 98% in the United States (CDC, 2018). Today, the current goal of state Early Hearing Detection and Intervention (EHDI) programs is to achieve equally high rates of follow-up after a failed newborn hearing screening (Joint Committee on Infant Hearing [JCIH], 2019; Ravi et al., 2016). Late identification was the norm for previous generations, who lacked a reliable mechanism for screening and diagnosing congenital hearing loss. Recent evidence supports developmental and language advantages to timely access to hearing aids and early intervention (Ching & Dillon, 2013; Yoshinaga-Itano et al., 2017). However, these benefits are only accessible after an infant's hearing status has been confirmed via diagnostic hearing assessment. After a failed newborn hearing screening, diagnosis entails an evaluation using auditory brainstem response (ABR) testing. The diagnosis makes early access to language learning possible through early intervention (via spoken language channels with the support of hearing technology or visual language channels; Hall, 2020).

Families cannot receive the benefits of early identification when access to services is delayed or they become lost to follow-up/documentation (LFU/D). LFU/D occurs when an infant who should receive further care such as a diagnostic hearing assessment or enrollment in early intervention services does not receive it (or follow-up cannot be documented by state EHDI personnel). Although LFU/D rates at the diagnostic hearing evaluation stage have improved over times, today they stand at 31.3% nationwide—a level that is unacceptably high (Subbiah et al., 2019). Failure to expeditiously move infants and families through the EHDI system threatens the effectiveness of programs, which can adversely impact children who are D/HH (Yoshinaga-Itano

[a]University of North Carolina Medical Center, Chapel Hill
[b]University of Iowa, Iowa City
[c]Iowa Department of Public Health, Des Moines
Correspondence to Caitlin Sapp: caitlin-sapp@uiowa.edu

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et al., 2017). Despite access to newborn hearing screening, children with permanent congenital hearing loss (PCHL) do not always benefit from access to early intervention.

Barriers to EHDI Program Improvement

State EHDI programs face unique challenges to ensure infants receive timely care. Because EHDI programs are state entities, each state's program may differ in their programmatic execution and the populations they serve. State-led quality improvement (QI) efforts may be well suited to address state-specific issues. Among the most frequently cited areas of concern in improving EHDI program quality are (a) lack of access to pediatric audiologists who offer infant diagnostic services, (b) issues related to rurality, and (c) barriers stemming from socioeconomic status (SES). We will review these three issues and their role in LFU/D and delayed care.

Pediatric Audiology Shortage

Since universal hearing screening was first proposed, there has been an ongoing concern about the lack of qualified pediatric audiologists who are skilled in infant hearing assessment (Madell, 2009; Oyler & Gross, 2000; Shaw, 2013; Shulman et al., 2010; White et al., 2010). The literature identifies several potential explanations behind this shortage, including a low emphasis on infant audiology practices in audiology training programs, poor reimbursement rates for time-intensive infant hearing evaluations with ABR, and the necessity for specialized equipment (Shulman et al., 2010). More recent data about pediatric audiologist access patterns gathered using the EHDI-PALS (Pediatric Audiology Links to Services) web-based directory suggest that these concerns remain valid (Nagaraj & Winston-Gerson, 2019). EHDI-PALS contains self-reported audiology clinic information to help families identify local providers that accept pediatric patients in different age categories (although there is no formal requirement that audiology clinics participate in the EHDI-PALS directory). Nagaraj and Winston-Gerson's state-specific analysis showed that there was large variability in the density of audiology facilities equipped to perform ABR evaluations. They observed a 15-fold difference between the state with the highest density (Maine, 1.3 diagnostic audiology facilities/1000 births) and the state with the lowest density (California, 0.09 facilities/1000 births). They also observed a mismatch between the patients that providers are reportedly able to service (i.e., diagnostic evaluation for children < 12 months) and the specific clinical activities they report offering (i.e., ABR testing). This mismatch suggests the possibility that infants are receiving repeat hearing screening when they require a true diagnostic hearing evaluation. This represents care that is off-guideline from recommendations laid out in the JCIH position statement (2019), which indicates that rescreening should only involve a single rescreen of both ears during the same visit. If the infant does not pass the rescreen in one or both ears, they should be immediately referred for a diagnostic ABR evaluation, with no additional rescreens. Over and above the inherent risk of missing children with mild hearing loss and auditory neuropathy spectrum disorder using current hearing screening technology, overscreening is associated with delayed identification in children with PCHL (Holte et al., 2012; Voss et al., 2016).

Rurality and Distance

A major concern for promoting EHDI timing goals is the disproportionate burden placed on rural families after an infant fails the newborn hearing screening (Shulman et al., 2010). Residents of rural communities experience delays accessing diagnosis (Bush et al., 2014), intervention (Barr et al., 2019), and hearing technology with appropriate follow up (Bush et al., 2013). Much of the previous research on newborn hearing health access and outcomes has taken place in rural regions of Appalachia. Investigators completed interviews with parents of children who needed EHDI follow-up (Elpers et al., 2016). Eighty-five percent of those parents (predominantly mothers) lived in counties considered "very rural." Their interviews revealed several themes related to access to care, challenges keeping follow-up appointments, and lack of resources. Families reported inconsistent information about clinics in their wider community that could provide ABR services and encountered lengthy wait times once a site was identified. Resource allocation factors included challenges with transportation, financial means to travel to appointments, and inability to take paid time off.

Barr et al. (2019) proposed alternative service delivery models such as telepractice and visiting specialists as a path to improve the broad range of service disparities for children with hearing loss in rural areas. Their work identified several consistent threads related to rural living. In some cases, they found that the impact of rural living compounds other negative prognostic factors such as low SES and poor/restricted coverage for related services and equipment. Families have indicated they were willing to participate in alternate service delivery models outside traditional clinics (Elpers et al., 2016).

SES

Families from disadvantaged backgrounds do not always access early hearing health care on par with families from more advantaged backgrounds (Shulman et al., 2010). This issue is of special concern given previous findings that infants from lower SES backgrounds are at increased risk of childhood hearing loss (Lantos et al., 2018). In their analysis, Lantos et al. attributed the increased PCHL rates to a high incidence of congenital cytomegalovirus infection and SES factors (with race as a proxy variable).

Lower SES families who pursue follow-up after a failed newborn hearing screening may experience delays compared to higher SES families (Holte et al., 2012). Medicaid insurance coverage can present an additional barrier related to SES. Medicaid is a publicly funded health insurance program that covers children and adults from low-income families or who meet other qualifications. While Medicaid policies provide broad coverage for diagnostic audiology and follow-up services, families must seek these services with a provider who has enrolled in the Medicaid program and

agreed to accept the reimbursement rate negotiated by the Centers for Medicaid and Medicare Services. Low rates of provider participation in state Medicaid programs impact family access, especially for hearing technology (McManus et al., 2010).

QI in EHDI

To help overcome these barriers to timely diagnostic services, the Iowa EHDI program developed a QI project focused on increasing access to infant diagnostic audiology services. QI projects in health care seek to improve the delivery of health services over the status quo through novel approaches to solve persistent problems (Deem et al., 2012; McLaughlin & Kaluzny, 2004). Within the EHDI domain, different states have applied QI principles to improve EHDI service delivery (Cockfield et al., 2012; Hunter et al., 2016; Russ et al., 2010; Tran et al., 2017). EHDI programs are well suited to *continuous quality improvement* (CQI) models. In CQI projects, the process of systems improvements is ongoing and does not carry the expectation of complete resolution of targeted problems. CQI requires a thorough understanding of a problem, a proposed mechanism for improvement, a framework for measuring the impact of the mechanism, and the capacity to integrate findings for future improvement. One common model that encapsulates these characteristics is the Plan–Do–Study–Act Model for Improvement (Taylor et al., 2014). This framework formed the basis of the current project.

Expanded Role for Educational Audiologists

This project expanded access to diagnostic ABR testing for newborn infants who fail the newborn hearing screenings by making these services available in Area Education Agencies (AEAs). An AEA is a regional education service division that provides special education and support services to public school districts (as well as nonpublic schools) within an assigned geographic boundary. Iowa is composed of nine AEAs (divided geographically) to provide these services throughout the state. On average, an AEA provides support for 37 school districts (range: 21–53). AEAs are a key component for school districts to meet federally mandated requirements under the Individuals with Disabilities in Education Act (IDEA) Part C and Part B (What is an AEA?, n.d.). Each AEA employs educational audiologists to meet the needs of school-age children who are D/HH in the classroom and infants and young children enrolled in Iowa's IDEA Part C early intervention program, Early ACCESS (Early ACCESS, n.d.). All AEA services fall under the Iowa Department of Education.

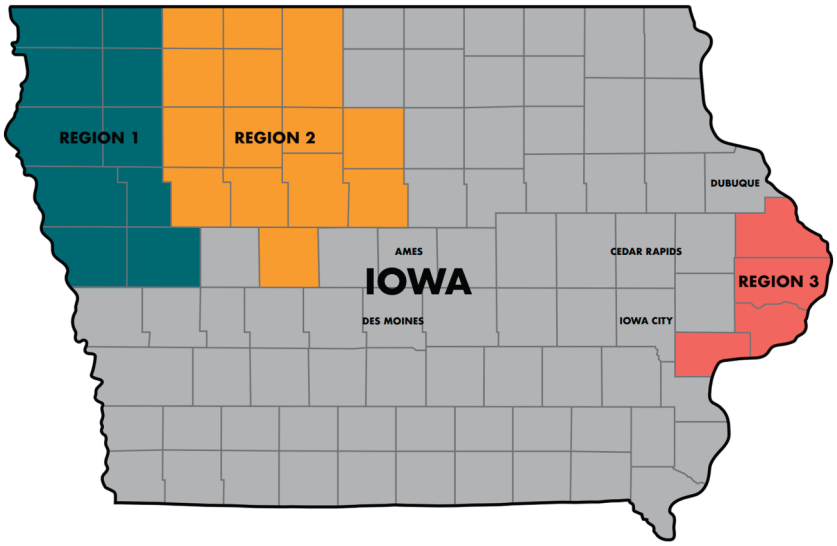
Iowa employs approximately 60 licensed educational audiologists throughout the nine AEAs and those audiologists deliver an array of hearing services. AEA audiologists identify hearing loss in older children through behavioral hearing evaluations, and guide students, families, and school teams during identification, diagnosis, and habilitation process. Children who meet eligibility requirements for AEA audiology services are supported throughout the duration of their educational careers (AEA Services, n.d.). Qualifying children from birth to 3 years old receive an Individual Family Services Plan (IFSP) to ensure a Free and Appropriate Public Education (FAPE). IFSPs are plans set forth to provide necessary educational services and early intervention to those children and their families and FAPE regulations guarantee that children with disabilities receive access to an education that suits their needs. Iowa's educational audiologists are a part of the IFSP team for infants with hearing loss. These services typically involve performing behavioral and functional pediatric audiology assessments, including air- and sometimes bone-conduction testing. Although educational audiologists may need to have an understanding of ABR measures, they typically do not have access to equipment for conducting evoked potential assessments (Johnson & Seaton, 2021).

Goals of the Current Project

We sought to develop a program that leveraged the existing network of educational audiologists distributed throughout the state of Iowa to improve access to diagnostic auditory brainstem response services. Even in communities with a shortage of clinical pediatric audiologists, educational audiologists are present to meet the educational needs of children who are D/HH distributed throughout states (McCreery, 2014). A QI project using educational audiologists had the potential to address several of the barriers identified above. From a rural geographic perspective, because AEAs are located throughout the state of Iowa, every family should have an educational audiologist within a 30-min drive. Iowa AEA audiology services are provided as part of the IDEA Part C program and are free to Iowa families. This stands to reduce the disproportionate financial burden on low SES families (compounded in the case of both high co-pays for services and the need to be away from work to keep appointments at distant clinics). Infants with Medicaid whose families experience difficulty finding participating providers are also eligible to receive services with AEA audiologists. Finally, by expanding the types of audiological services that our educational audiologists perform to include ABR evaluations, we will increase the total number of potential sites for diagnosis in the state of Iowa. While our project does not directly address the persistent shortage of pediatric audiologists, it redeploys existing audiology staff in a new way to meet the specific needs of infants who do not pass the newborn hearing screening in rural communities. Furthermore, educational audiologists have experience working with families of children with hearing loss on a long-term basis. This experience may be beneficial when counseling parents of newly identified children; for example, including educational audiologists in the initial diagnostic process could facilitate the transition from screening to diagnosis to early intervention.

At the outset of the QI project in each participating AEA (see Figure 1), the Iowa EHDI program purchased diagnostic ABR equipment (Vivosonic or Interacoustic Eclipse

Figure 1. Map of Iowa and the Area Education Agency regions targeted by the quality improvement Project.



units) and scheduled sessions with a representative from the vendor. Audiology technical support personnel from the state EHDI program participated in these trainings. Each site received a diagnostic evoked potentials system. Both clicks and tone bursts were used during the ABR testing. Although the ABR systems were capable of doing both air and bone conduction, only air conduction was used on a regular basis. The EHDI program covered the initial cost of the equipment and consumables and each AEA covered ongoing maintenance costs (i.e., calibration) and the cost of consumables (e.g., electrodes, earphone tips, abrasive gel) unless the EHDI program secured other grant funding. Two pediatric audiologists, experienced in performing and interpreting ABRs, provided ongoing consultation and oversight of the ABR testing. Educational audiologists were asked to send ABR waveforms with their clinical interpretations to these pediatric audiologists for review initially. Once the educational audiologists felt comfortable interpreting the waveforms independently, they were not required to send the waveforms to the pediatric audiologists unless they had questions. These two audiologists were also available to the educational audiologists if they had additional needs (e.g., troubleshooting equipment, managing electrical noise). The ABR testing took place took place in an exam room or sound booth at the AEA office.

As part of the Plan–Do–Study–Act QI framework, we address three research questions related to its goals:

a. How has the QI Project (expansion of regional educational audiology services to include diagnostic ABR) changed average age at diagnosis, compared to preproject Baseline?

b. How has the QI Project changed the average distance that families travel for diagnosis, compared to preproject Baseline?

c. How has the QI project impacted the likelihood that infants receive on-guideline audiology care compared to preproject Baseline?

Method

To address the research questions outlined above, we analyzed infant records during a Baseline and a QI Project time interval, using the data tracked by the state EHDI program.

Iowa Department of Public Health EHDI data

We received a data set of de-identified records after completing a data-sharing agreement with the Iowa Department of Public Health (IDPH) EHDI program. Among several variables, the data set includes birth, screening, and hearing loss outcome information from all counties within the three AEAs involved in this project (see Table 1). These AEAs have participated in this project for the longest duration and therefore have the most data available for analysis.

The Iowa EHDI program tracks birthing and diagnostic data using eScreener Plus (eSP) software developed by OZ Systems. This tracking system records information including the birth location, date, time weight at birth, demographic information, presence or absence of risk factors for hearing loss, and hearing screening results. Each infant's record is updated as information becomes available (e.g., changes to demographics, additional hearing screenings, or diagnostic results). All the infants in our study had previously failed a newborn hearing screening and an outpatient rescreening when indicated (i.e., infants from the well-baby nursery). Per Iowa state recommendations, all outpatient rescreening appointments were to have been completed before 1 month of age.

Table 1. List of extracted variables from the OZ database for infants in this study.

Date of birth
Sex
Race/ethnicity
City
State
Zip code
Birthing facility
Birth screen provider
Outpatient screen provider
Assessment provider
Patient outcome (e.g., deceased, moved out of state, complete in process)
Hearing outcome (e.g., bilateral hearing loss complete, unilateral hearing loss-in process, normal hearing)
Birth screen date
Birth screen outcome (e.g., bilateral pass, unilateral pass)
Outpatient screen outcome (e.g., bilateral pass, unilateral pass)
Audiological assessment outcome (e.g., bilateral hearing loss complete, unilateral hearing loss-in process, normal hearing)
First test type
First diagnostic session date
Insurance type

All EHDI records reviewed were extracted from eSP by the IDPH during the summer of 2020, de-identified, and shared via a secure data transfer with the research team. Table 1 lists the variables extracted from eSP. This project was completed under the approval of the University of Iowa Institutional Review Board under a data-sharing agreement with IDPH. The University of Iowa Institutional Review Board determined that this project did not meet the criteria to be considered human subjects research.

Baseline and QI Project Conditions

For statistical comparison, we classified records into two groups: pre- and postonset of our QI project ("Baseline" and "QI Project"). Because the three AEAs began seeing patients for nonsedated ABR testing at different times, the date cutoffs are different for each region. We analyzed a total of 18 months of Baseline data and up to 55 months of QI Project (see Table 2 for inclusive dates by AEA region). We included all infants born within participating AEAs who failed the newborn hearing screening, including those who were eventually identified as having typical hearing after diagnostic testing. False positives (children with typical hearing who do not pass the initial newborn hearing screening or rescreening) represent a significant percentage of infants who receive early diagnostic evaluation due to the nature of population-level screening programs (Clemens et al., 2000). Thus, it was important to include the records of infants with typical hearing as part of the project.

We performed all data manipulation, analyses, and visualizations in RStudio 1.1.463, using the *epitools, dplyr,* and *ggplot2* packages, aside from our distance calculation for which we used Microsoft Excel calculations with latitude and longitude coordinates (Aragon, 2020; Wickham, 2016; Wickham et al., 2020). For both groups, we generated new variables to represent an infant's unadjusted age (in days) at the time of their diagnostic evaluation using their date of birth and the dates of service. We grouped infants by their date of birth: infant records with birth dates before the start of the project ("Baseline") and infant records during the active phase of the project ("QI Project"). We compared ages at first diagnostic exam across groups. Additionally, we created a new variable to account for distance traveled (in miles) for their diagnostic assessment. We used their home ZIP code and the ZIP code of their first diagnostic facility. We did not make adjustments to the distances calculated between home ZIP code and provider ZIP code to account for driving distances.

Analyses

We compared the distance traveled for the first diagnostic evaluation and child age in days at the first diagnostic evaluation using *t* tests with adjustments for unequal variance. To examine these differences by AEA Region, we performed follow-up two-way analyses of variance (ANOVAs) with condition (Baseline vs. QI Project) and region as the independent variables. Finally, to assess the quality of diagnostic assessment that infants received during QI Project, we calculated an odds ratio and confidence interval associated with receiving on-guideline audiology care during the first diagnostic hearing evaluation with an audiologist as a binary outcome.

Results

Table 3 shows the demographic makeup of our Baseline and QI conditions. To accurately compare metrics in the Baseline and QI Project phases, we were obliged to exclude a large number of infant records that were LFU/D from data analysis in the Baseline and QI Project (detailed outcome data is listed in Table 4). We classified infants as LFU/D when records did not contain documentation that they received a diagnostic evaluation after a failed newborn hearing screening. Table 4 contains the reason for the lack of a documented outcome as listed in their EHDI record. The most common reason for LFU/D was some permutation of EHDI staff having lost contact with families. Just over 32% of infants were LFU/D during the QI Project, which was significantly lower than the 42% of infants lost during the Baseline period (X^2 [1, n = 670] = 5.163, p = .023). Table 5 compares demographic details for included infant records and those that we excluded due to LFU/D. In general, excluded records were more likely to come from racially and ethnically diverse backgrounds and have Medicaid health insurance. Although our total data set shows a preponderance of male infants, this difference is even more pronounced in the included set of records. Males represent 62% of records in the Baseline group and 66% of the QI Project group.

There was wide utilization of ABR services offered in targeted AEAs during the QI Project. In Region 1,

Table 2. Baseline and QI Project cutoffs and the relative contributions of records by each AEA region to our pooled sample of 671 records.

AEA region	Baseline	Number of records	QI project	Number of records
AEA Region 1	02/01/2014–07/31/2015	80	08/01/2015–12/31/2019	162
AEA Region 2	06/01/2015–11/30/2016	110	12/01/2016–12/31/2019	54
AEA Region 3	02/01/2016–07/31/2017	159	08/01/2017–12/31/2019	106
Total:		349		322

Note. QI = quality improvement; AEA = Area Education Agency.

educational audiologists completed 35 diagnostic ABR exams and identified 12 cases of permanent childhood hearing loss (PCHL; out of 23 total cases of PCHL identified in Region 1 during the study period). In Region 2, educational audiologists completed 44 ABR exams and identified four cases of PCHL (out of nine total cases). Finally, in Region 3, educational audiologists completed five ABR exams and identified three cases of PCHL (out of 16 total cases).

Age at First Exam

To address our first research question, we compared infant age at the first diagnostic exam in the Baseline and QI Project conditions. Following implementation of our QI Project, average age at first diagnostic exam significantly decreased from an average of 95 days of life (SD = 103) to an average of 67.8 days in the targeted AEA regions (SD = 75.4; p = .0014; see Figure 2). Follow-up two-way ANOVA testing did not identify a significant main effect of AEA Region on this outcome, $F(2,418) = 1.39$, $p = .25$.

Distance Traveled for Diagnostic Exam

To address our second research question, we then compared the distance that families traveled from their home ZIP code to complete their first diagnostic assessment with an audiologist. A t test with Welch's adjustment for unequal variance revealed that following the implementation of our QI Project, the average distance significantly decreased from 97.8 miles (SD = 58.9) to 75.3 miles (SD = 53.6; $p < .0001$; see Figure 3). We then performed a two-way ANOVA to test the consistency and strength of this relationship across our three AEA Regions. We identified main effects of AEA region, $F(2, 416) = 5.778$, $p < .01$; condition, $F(1, 416) = 17.87$, $p < .001$; and a significant interaction, $F(2, 416) = 7.89$, $p < .001$. Figure 4 shows this comparison. Post hoc Tukey analysis showed that AEA Region 1 alone experienced a significant decrease in the distance that families traveled for their first diagnostic assessment between the Baseline and QI Project conditions, decreasing from an average distance of 117 miles (SD = 65.6) to 66.5 miles (SD = 61.5; $p < .001$). There were no significant changes in average distance traveled for first diagnostic exam in Region 2 or Region 3.

On-Guideline Audiological Care

Finally, for our third research question, we examined the types of clinical activities that audiologists completed at the first diagnostic exam in our targeted regions during the QI Project interval (see Table 6). Per JCIH (2019) guidelines, the appropriate next step for each infant was a diagnostic hearing evaluation using ABR. Among infants born in the targeted regions, we calculated the odds of receiving a diagnostic ABR at the first hearing evaluation during the QI Project compared to Baseline (see Figure 5). We found that infants who received on-guideline care (received an

Table 3. Demographic information about our Baseline and QI Project infant groups, excluding infants without final diagnosis.

Demographic information	Baseline n = 205	QI Project n = 217
Infant sex, female (n; %)	78; 38%	73; 34%
Medicaid insurance coverage (n; %)	79; 39%	13; 6%
Hispanic or Latino (n; %)	39; 19%	45; 21%
Maternal race		
American Indian	1	2
Asian	4	9
Black	10	13
White	168	163
Multirace	5	4
Other	17	26
Final diagnosis of HL (n; %)	50; 24.4%	48; 22.1%

Note. QI = quality improvement; HL = hearing loss.

Table 4. Details for excluded records from each AEA and the reported reasons for incomplete outcomes.

Total excluded records (N = 248)	AEA 1 (n = 88)	AEA 2 (n = 53)	AEA 3 (n = 107)
In process	1	1	3
Deceased*	1	2	3
Family declined*	15	13	15
Lost contact	29	23	39
Moved out of state	14	0	7
Unable to contact/ contacted but unresponsive	28	14	40

Note. AEA = Area Education Agency.

*These categories were not included in lost to follow-up/documentation calculations.

Table 5. Demographic information in records that were included in our analyses and records that were excluded from our analyses (i.e., records with incomplete follow-up documentation).

Demographic information	Excluded records *n* = 249	Included records *n* = 422
Infant sex, female (*n*; %)	109; 43.8%	151; 35.8%
Medicaid insurance coverage (*n*; %)	82; 32.9%	92; 21.8%
Hispanic or Latino (*n*; %)	63; 25.3%	84; 19.9%
Maternal race		
American Indian	9	3
Asian	8	13
Black	29	23
White	166	331
Multirace	5	9
Other	32	43

ABR or auditory steady-state response at their first exam) were 2.52 times more likely to have been in the QI Project condition compared to the Baseline condition (95% CI [1.68–3.76]). This advantage was statistically significant ($p < .0001$).

Audiologists' Feedback About QI Project

Educational audiologists who participated in the QI project were informally surveyed in July 2018 (after all three AEAs had initiated ABR testing) regarding the benefits and weaknesses of performing unsedated ABRs as part of their services. Audiologists provided the following statements about the benefits:

- Wait to get in for diagnostic assessment is short/less time to worry
- Helps meet the national 1–3–6 goals
- Families do not have to travel long distances

Figure 2. Boxplot comparing the age (in days) at infant evaluation in the Baseline and QI Project conditions. The red dashed line represents the age cutoff for diagnosis recommended by the Joint Committee on Infant Hearing 2019 position statement. Group means appear in red.

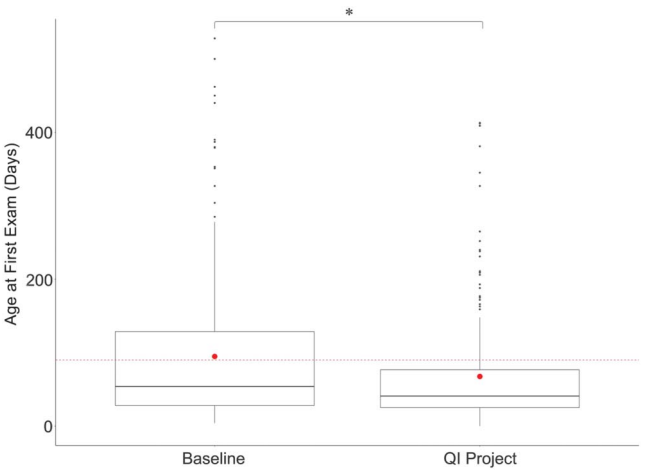
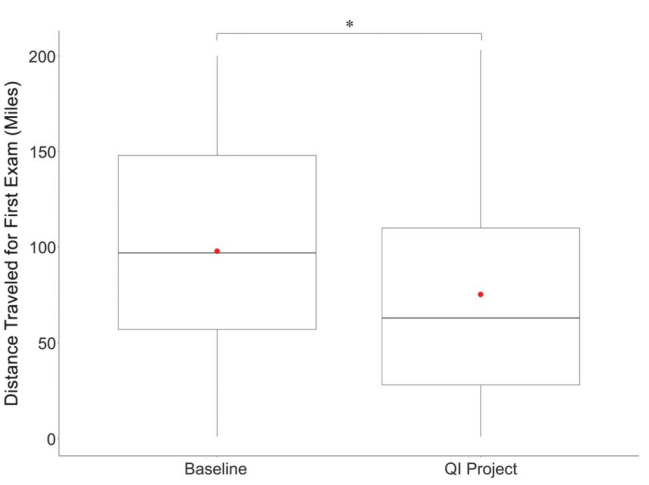


Figure 3. Boxplot comparing the distance (in miles) that families traveled for infant evaluation in the Baseline and quality improvement (QI) Project conditions. Group means appear in red.



- Equipment is mobile, so if a parent cannot get to the location farther away for testing, the AEA can take it to an AEA satellite office that is closer
- Hospitals appreciate of local referral source versus sending (the patients) out of state
- Agency diagnosing is same agency providing early intervention services so quick referral
- Less time off work for families without resources and easier to comply with requests for sleeping baby
- Families leave with a better understanding of what test may be needed because the audiologist can

Figure 4. Boxplot comparing the change in distance traveled (in miles) for first hearing evaluation in the Baseline and QI Project conditions, stratified by Area Education Agency (AEA) region. Group means appear in red.

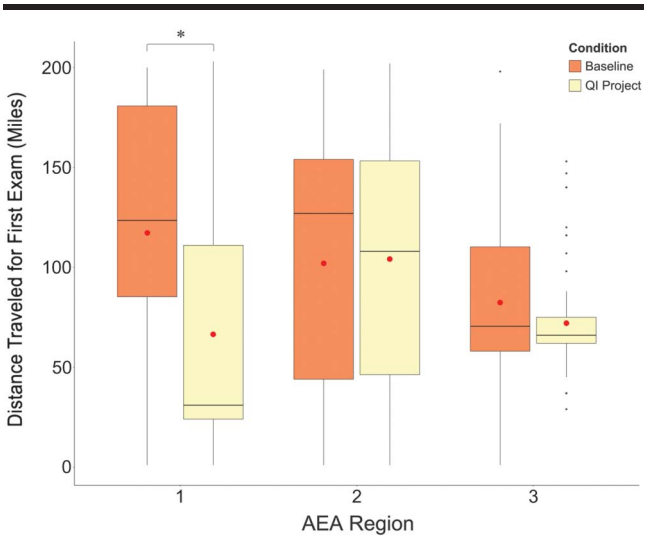


Table 6. Detailed information about the audiology care that infants received at their first diagnostic assessment during the Baseline and QI project conditions. On-guideline care is denoted in bold font.

Audiology care	Baseline (*n* = 205)	QI project (*n* = 217)
ABR only	**30**	**28**
ABR/ASSR	**3**	**2**
ABR/ASSR + OAE	**1**	**17**
ABR/ASSR + Tympanometry	**13**	**10**
ABR/ASSR + Tympanometry + OAE	**20**	**61**
OAE only	29	14
OAE + Tympanometry	75	63
Tympanometry only	13	7
VRA only*	1	0
VRA + Tympanometry*	3	1
VRA + OAE*	1	1
VRA + Tympanometry + OAE*	8	5
Not reported	8	8

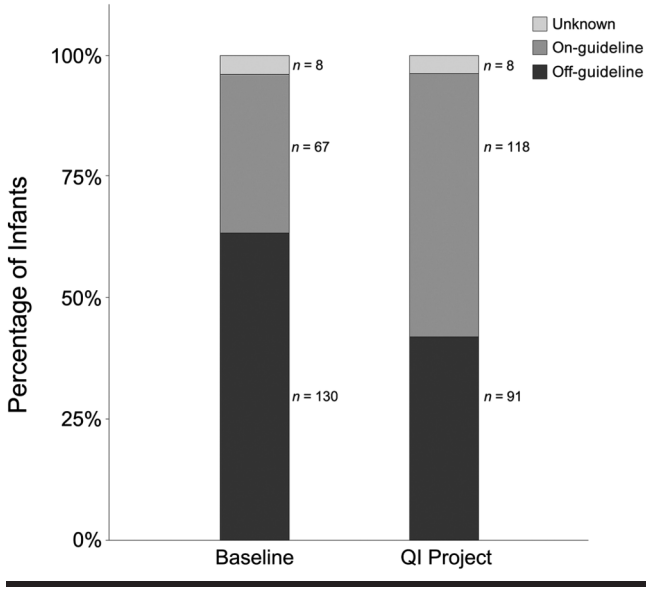
Note. On-guideline care is denoted in bold font. QI = quality improvement; ABR = auditory brainstem response; OAE = otoacoustic emissions; VRA = visual reinforcement audiometry.

*May reflect infants who did not receive timely assessments after failed newborn hearing screening and were first evaluated at older ages.

explain it to them or answer questions about next steps

- Families can be connected quickly and easily to family support (e.g., deaf mentor)

Figure 5. Distributions of on-guideline and off-guideline audiology care in the Baseline and QI Project conditions. Among infants who received on-guideline audiology care, the odds they were in the QI Project condition were 2.52 times those they were in the Baseline condition (95% CI [1.68, 3.76], $p < .001$). On-guideline care entails any first diagnostic exam that included the use of auditory brainstem response technology (or auditory steady-state response) following a failed newborn hearing screening. QI = quality improvement.



- Infants can be referred straight from outpatient screen to AEA rather than wait for order from primary care physician
- Infants can avoid sedation with immediate referral
- Assists in timely child-find within the AEA system and decreases delay. The educational audiology referral can begin without the delay incurred while waiting for an appointment to a diagnostic center.

Compared to the reported benefits, audiologists reported a smaller number of weaknesses. These weaknesses involved concerns about sustainability and the amount of time it took to do the assessment and paperwork.

Discussion

We developed a QI project to address three factors that drive poor access to diagnostic evaluation after a failed newborn hearing screening. We increased the number of providers offering nonsedated hearing evaluations with ABR by training educational audiologists (or offering refresher training) and providing ABR equipment in regional AEA locations. This reduced the geographic burden on families who live in rural communities by bringing needed services to them. By offering these services in an educational audiology model, our project increased access to early diagnostic audiology testing infants from all SES backgrounds.

This project leveraged existing educational audiology networks and thereby expanded access without the use of additional staff. This expanded access benefits families whose children are diagnosed with PCHL by allowing them to seek intervention and medical management earlier than peers who are identified later. It also benefits families of children with typical hearing and the state EHDI program. Regardless of findings, parents can receive information about their child's hearing status sooner and receive it closer to home when a greater number of pediatric audiologists provide infant diagnostic hearing evaluations in more rural communities. Children diagnosed at younger ages may be less likely to require a sedated exam to ascertain hearing status (JCIH, 2019). By effectively detecting typically hearing children and moving them out of active EHDI case management, we can direct more resources toward supporting families of children with PCHL.

QI Project Effectiveness

To test the impact of our QI Project on EHDI program quality, we used an administrative data set to examine age at first diagnostic evaluation and distance traveled for first evaluation. Research with administrative data gleans additional value out of state health resources devoted to tracking health outcomes. These actions represent the "study" component of our Plan–Do–Study–Act QI framework.

During the QI Project period, we saw the distance traveled by families for the first diagnostic audiology exam drop significantly, although this benefit appeared to be concentrated within a single targeted AEA (Region 1). Region 1 is located in the extreme northwest corner of the state, and

these changes may reflect fewer families seeking diagnosis with an out of state provider in Nebraska or South Dakota during the QI Project. During the QI Project condition, many families continued to receive a diagnostic exam at a non-AEA audiologist. By training additional audiologists to provide highly skilled infant hearing evaluations as part of this project, however, we observed an overall shift in the geographic burden families faced for diagnosis. Both these findings speak directly to the potential for this QI project to address the rural hearing health care concerns identified in Barr et al. (2019) by expanding the number of providers and decreasing the distance between patients and providers. When there are fewer audiologists and audiology sites offering ABR services in the community, each diagnostic site who does offer them must shoulder a greater proportion of the caseload in their catchment region. Resulting concentration of services at diagnostic sites can lead to lengthy waiting times for ABR appointments. Delays in appointment availability has figured among the top concerns of state EHDI leadership (Muñoz et al., 2011) and will necessarily lead to later ages at hearing confirmation.

We also observed average age at first diagnostic evaluation drop significantly since the rollout of our QI Project in the targeted regions. Younger age at first exam is positively related to the likelihood of confirmed diagnosis of PCHL by 3 months of age (Shanker et al., 2019). Improving age at first hearing evaluation may prevent delays from having cascading effects on timeliness of other intervention steps in infants with confirmed PCHL (Bush et al., 2013; Holte et al., 2012).

Our final metric found that our QI Project was associated with increased odds that infants will receive a true diagnostic hearing assessment at their first appointment with an audiologist. This is a promising evidence that our QI Project not only expands access to care but also may lead to improved implementation of JCIH guidelines. While our findings from the QI Project condition reveal improvements over time, a large number of families continue to receive off-guideline care during their first audiology assessment (i.e., receive repeat hearing screening or tympanometry alone). One potential explanatory factor is that, in non-AEA settings, families may be required to have an initial in-person appointment to establish care with a provider before scheduling a full ABR or are first directed to an otolaryngologist after failed newborn hearing screening without the capacity to perform infant hearing evaluations. The redundant hearing screening may therefore be an incidental occurrence as part of an initial intake visit. Future research should examine the practice patterns that lead to this mismatch between what appointment infants need and the appointment they have scheduled (e.g., referral processes, information sharing, provider education).

Limitations

There are several limitations in this QI project analysis that are worth noting. First, there is a possibility that we did not truly capture a baseline for AEA regions. Prior to the current QI Project, our state EHDI program experimented with the use of telepractice to perform ABRs in rural Iowa. This creates the risk that our Baseline level of access in some regions was artificially inflated compared to other regions. However, during the tenure of the telehealth project, staff performed only 12 ABRs over 4 years due to logistic and billing constraints. The risk of bias that this introduces would be toward null findings: had the previous QI project increased access to ABR evaluations, we would have been less likely to detect a significant shift.

Another limitation of our study is our inability to capture how much of the improvements we observed are attributable to global improvements in EHDI service delivery during the period and how much is attributable to our QI Project. The span we included was short and, to our knowledge, does not overlap with any other major QI efforts in our state. We also used ages and distances associated with an infant's first diagnostic assessment. The first diagnostic evaluation represents a best-case scenario: an infant's family receiving a definitive diagnosis as typical hearing or as having a PCHL during their first encounter with an audiologist. We know from recent epidemiological literature that families often require multiple appointments to receive a firm diagnosis (Awad et al., 2019; Holte et al., 2012). Finally, we used residential ZIP codes to determine the distance traveled for first diagnostic assessment instead of home address. Our data set contained de-identified infant records which precluded the use of information such as home address which could be linked to subjects. We applied this categorization approach in the QI Project period as well as the Baseline period and thus do not believe that we introduced nonrandom error.

Another limitation is that we did not systematically obtain feedback from educational audiologists who were involved in the project (although we did query the audiologists about their attitudes regarding benefits and weakness of the program). An important future direction would be to collect surveys from the participating AEA providers. These surveys could include specific questions, such as the administrative burden of conducting the ABRs in addition to their other duties in the schools.

Although our project takes advantage of existing audiology providers to fill gaps in access to infant hearing evaluation, its implementation does not solve the problem of an overall shortage of pediatric audiologists or the need for greater audiology participation in state Medicaid programs. The need remains for expanded service provision in rural communities, especially for infants with PCHL who require prompt fitting of amplification and medical management (which do not fall under the purview of AEA services).

Clinical Implications

One final potential benefit of the proposed model for diagnostic services is the opportunity for service integration between educational audiologists and early intervention providers. In our state, AEAs also administer the Early ACCESS program. Early ACCESS is Iowa's statewide program for early intervention services under the IDEA Part C.

The same audiologists who identify hearing loss under this QI Project will go on to provide audiology support for these infants and families throughout their educational tenure. Accessing diagnostic services within an education audiology system eliminates the need for handoff between clinical audiologists and early intervention teams. Poor handoff is thought to contribute to relatively low rates of early intervention enrollment (Conroy et al., 2018), even in areas with high rates of follow up for diagnostic services. Future research about this QI Project should examine its potential for improving rates of Early ACCESS enrollment and parent satisfaction with integrated diagnostic and intervention services.

Conclusions

Our goals in the current study were to describe a QI project taking place through a partnership between the Iowa EHDI program and educational audiology departments throughout the state and measure its impact on several indicators of quality. With the support of the state EHDI department (through access to ABR equipment, technical support, and training), educational audiologists in Iowa began performing infant diagnostic testing in rural communities where there is otherwise a lack of services. Using a Plan–Do–Study–Act framework, we measured significant decreases in the distance traveled for diagnostic evaluation and age at first diagnostic evaluation for infants born in regions targeted by our QI Project. We also found that children born in the targeted areas during the QI Project had greater odds of receiving care that complied with recommendations in the JCIH position statement. This QI Project shows potential for expanding access to diagnostic services in rural communities and increasing the average quality of care that infants receive after having failed the newborn hearing screening.

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