Clinical Focus

Meeting the Joint Committee on Infant Hearing Standards in a Large Metropolitan Children's Hospital: Barriers and Next Steps

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Purpose: The aim of this study was to determine how a large metropolitan children's hospital's practices align with the Joint Committee on Infant Hearing (JCIH) 1-3-6 guidelines (diagnose hearing loss by 3 months of age, fitted with hearing aids within 1 month of diagnosis, and enroll in early intervention by 6 months of age) and examine variables that have impacted meeting these guidelines. This hospital is not a birthing hospital. Therefore, the first recommendation (hearing screen by 1 month of age) was not evaluated.

Method: One hundred forty-one auditory evoked potential evaluations for infants under the age of 6 months were reviewed for this study. Data were only gathered for infants identified with a bilateral hearing loss ($n = 34$). The following was recorded: degree of hearing loss, number of diagnostic sessions over time, the percentage of infants who transitioned to hearing aid fittings, and the age at which JCIH benchmarks were accomplished.

Results: Sixty-two percent of infants were diagnosed with hearing loss by 3 months of age, 48% of infants were fitted with hearing aids by 4 months of age, and the average age of infants enrolled in early intervention was 4.58 months. Seventy percent of infants were fitted within 1 month of the diagnosis of hearing loss. The identified variables that led to the hearing aids being fitted greater than 1 month after the diagnosis are as follows: cancellations/missed appointments, middle ear involvement, and mild hearing loss.

Conclusions: Results of this internal audit revealed opportunities for growth in better meeting and exceeding JCIH recommendations of diagnosis by 3 months of age and hearing aid fitting within 1 month of diagnosis. Adjustments in the scheduling process and appointment options have been implemented in response to these results. Additional examination of why these recommendations are not being met and what can be done to achieve them is needed.

Each year, one to three per 1,000 infants receive a diagnosis of permanent hearing loss (Centers for Disease Control and Prevention, 2012). Prior to universal newborn hearing screenings, children were not diagnosed with hearing loss until almost 2 years of age, if not later (Halpin, Smith, Widen, & Chertoff, 2010; Harrison & Roush, 1996; Ruben, 1997; Sininger et al., 2009; Spivak, Sokol, Auerbach, & Gershkovich, 2009; Stein, Jabaley, Spitz, Stokley, & McGee, 1990; White, 2003; Yoshinaga-Itano,

Sedey, Coulter, & Mehl, 1998). Without early intervention, children with hearing loss are at risk for falling behind their normal-hearing peers in language, social-emotional, and academic skills (Tomblin et al., 2015; Vohr et al., 2008, 2010, 2011; Yoshinaga-Itano et al., 1998). Furthermore, these delays may result in lower education and employment levels in adulthood (Holden-Pitt & Diaz, 1998). Early identification and intervention services have been shown to lead to mean expressive and receptive language skills similar to children without hearing loss (Kennedy et al., 2006; Moeller, 2000; Yoshinaga-Itano, Coulter, & Thomson, 2000; Yoshinaga-Itano et al., 1998). Recent studies have contributed to the existing knowledge that early hearing aid fittings lead to better speech and language outcomes (Sininger, Grimes, & Christensen, 2010; Sininger et al., 2009; Tomblin et al., 2015; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014).

The Joint Committee on Infant Hearing (JCIH) was established in 1969. Although it has evolved over time, its primary role is to create position statements recommending

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preferred practices in screening, early identification, fitting of amplification, and intervention for children at risk for or with hearing loss based on current research. The current JCIH (2007) recommendations, referred to as the *1-3-6 model*, are as follows: (a) All infants should have their hearing screened by no later than 1 month of age; (b) those who do not pass the hearing screening should receive a comprehensive audiologic evaluation by no later than 3 months of age; and (c) infants with a confirmed diagnosis of hearing loss should be enrolled in appropriate early intervention services, including the fitting of hearing aids when appropriate, by no later than 6 months of age (JCIH, 2007). The JCIH (2007) recommends the fitting of amplification within 1 month of the hearing loss diagnosis. Yoshinaga-Itano, Sedey, Wiggin, and Chung (2017) demonstrated data from several states across the United States that indicate that all three milestones must be met for the benefits of early intervention to be observed. Specifically, if an infant misses any one of the three entry points of 1-3-6, then delays in language outcomes are observed (meaning language quotients less than 80). Furthermore, Vohr et al. (Vohr et al., 2012; Vohr, Topol, Watson, St. Pierre, & Tucker, 2014) found that completion of this process by 3 months of age led to better expressive and receptive language outcomes at preschool and elementary school ages. In light of these results, there have been discussions among early hearing detection and intervention (EHDI) professionals of transitioning to a 1-2-3 model: screen by 1 month of age, diagnose by 2 months of age, and enroll in early intervention by 3 months of age. Transitioning this into practice may be quite challenging though. Holte et al. (2012) revealed that only 32% of participants met all 1-3-6 guidelines in their multicenter study (i.e., Outcomes in Children With Hearing Loss).

Challenges to Meeting the JCIH Guidelines

Various barriers have been identified that may prevent families from achieving the JCIH 1-3-6 benchmarks. These include provider-, patient-, and family-related barriers. Provider-related barriers include limited access to audiologists with pediatric experience, appointment wait times, and delay in diagnosis of hearing loss due to multiple rescreenings and diagnostic tests (Holte et al., 2012; MacNeil, Liu, Stone, & Farrell, 2007; Munoz, Blaiser, & Barwick, 2013). Patient-related barriers include patient comorbidities, unilateral or mild hearing loss, general health/neonatal intensive care unit (NICU) stay, and presence of otitis media (Coplan, 1987; Dalzell et al., 2000; Harrison & Roush, 1996; Holte et al., 2012; Moeller, Eiten, White, & Shisler, 2006; Moeller, White, & Shisler, 2006; Walker, Spratford, Ambrose, Holte, & Oleson, 2017). Family-related barriers include family understanding of the importance of follow-up, subjective observation of the child's response to sounds, acceptance of hearing loss, work schedules, and socioeconomic status (Folsom et al., 2000; Holte et al., 2012; MacNeil et al., 2007; Munoz et al., 2013).

As noted above, many studies have documented the impact of these barriers on meeting the JCIH guidelines.

Munoz et al. (2013) reported a median delay of 2 months between the initial diagnosis and the fitting of hearing aids. Parents reported the most significant barriers to the hearing aid fitting were (a) cost, (b) accepting the need for the hearing aids, and (c) wait time for the appointment. MacNeil et al. (2007) examined the timeliness of diagnostic evaluations in Massachusetts. The most frequently reported barriers to these appointments included inconvenient appointment times, too long travel time to an appointment, difficulty in scheduling an appointment, difficulty in finding child care, and not having time off from work. Of those diagnosed with hearing loss, 35% were diagnosed in one appointment, 28% were diagnosed in two appointments, 15% were diagnosed in three appointments, and 22% were diagnosed in greater than three appointments. Reasons that greater than one test was needed included fussiness of the baby and inconclusive/unclear results.

Because of difficulties meeting the JCIH guidelines documented in the literature (Holte et al., 2012; MacNeil et al., 2007; Munoz et al., 2013), this project was undertaken to determine whether a quality improvement project was necessary at our facility. In order to determine need, we first examined if we were meeting the JCIH standards (JCIH 2000, 2007) to diagnose hearing loss by 3 months of age, fit hearing aids within 1 month of diagnosis, and enroll in early intervention by 6 months of age. Specifically, if the hearing loss diagnosis is made by 3 months of age as recommended in the JCIH position statement, this would mean infants should be fitted with hearing aids no later than 4 months of age. Therefore, we examined the age at diagnosis of hearing loss, age at hearing aid fitting, and duration of time between diagnosis of hearing loss and fitting of amplification. Second, we examined potential variables that impacted (either positively or negatively) meeting these benchmarks, which could be captured using a chart review.

This project was completed at Children's Hospital Colorado, a large metropolitan children's hospital that has eight sites capable of diagnosing and treating infants and children with hearing loss across the Denver metro and Colorado Springs regions. Patients from nearby states and outlying regions of Colorado are seen at this hospital. In the state of Colorado in 2014, 74 infants were diagnosed with a bilateral hearing loss. Over the course of the study, 34 infants were diagnosed with a bilateral permanent hearing loss at our hospital. Based on these statistics and the total number of infants identified with bilateral hearing loss in the state of Colorado in 2014, one can extrapolate that this hospital serves a majority of infants identified with hearing loss in Colorado each year.

Method

A retrospective chart review was conducted for infants who were under 6 months of age and received an auditory evoked potentials (AEP) evaluation at our facility between July 1, 2014, and December 31, 2014. These dates were selected with the goal of infants having completed the process from diagnosis of hearing loss through fitting of

amplification, with a sample size that was manageable for the purposes of determining if a formal quality improvement project was needed. Diagnostic AEP evaluations included otoscopy, tympanometry, distortion product otoacoustic emissions, click auditory brainstem response, and auditory steady-state response. Auditory steady-state response was utilized to obtain frequency-specific thresholds, which allows for better fitted hearing aids. It was always included as one part of a comprehensive test battery reflecting the cross-check principle (Jerger & Hayes, 1976) and is listed as an option for infant audiologic testing in recent guidelines for pediatric assessment, such as the American Academy of Audiology's (AAA) Audiologic Guidelines for the Assessment of Hearing in Infants and Young Children (AAA, 2012). We utilized the Colorado Department of Public Health database to examine how many infants participated in early intervention and when they had their first contact with a Colorado Hearing Resource Coordinator, who is the point of entry into early intervention for children with hearing loss in Colorado.

Participants

Data were entered for infants who were between 0 and 6 months of age when their initial AEP evaluation was completed. Information was collected for these infants from the time they entered the newborn hearing screening process at our facility (when applicable) until the time of referral to Part C early intervention services for infants and toddlers. Data were entered from the infants' electronic medical record into the database by an audiology graduate student. The data were verified by the authors of this article.

During this 6-month period, 141 infants received diagnostic AEP evaluations. Diagnostic evaluations were completed in accordance with the AAA (2012) and state of Colorado (Colorado Department of Public Health and Environment, 2004) guidelines. Information is provided regarding the number of diagnostic sessions over time for this group. Once the diagnostic process was completed (i.e., deemed enough information for the audiologist to proceed with a hearing aid fitting), data were only gathered for infants with a bilateral hearing loss ($n = 34$). Degree of hearing loss is reported for the better hearing ear. Of the infants diagnosed with hearing loss, 44% of the infants had private insurance, 50% had Medicaid, and 6% had Child Health Plan Plus. Child Health Plan Plus is a public, low-cost health insurance program in Colorado that is available for children whose parents do not qualify for Medicaid but do not earn enough to pay for private health insurance (Child Health Plan Plus, 2017). Insurance status was considered as a proxy for socioeconomic status (Marcin, Schembri, He, & Romano, 2003). For the 34 infants with hearing loss, we have described the degree of hearing loss, the percentage of infants who transitioned to hearing aid fittings, and the age at which the JCIH benchmarks were met. Data were not available to describe the JCIH benchmark of hearing screening by 1 month of age because screens are typically completed at the birth hospital, and this facility

is not a birthing hospital, except for very high-risk pregnancies. Therefore, this article focuses on the diagnosis of hearing loss, the transition to hearing aids, and the initiation of early intervention.

Independent-samples t tests revealed no significant differences between outcome measures comparing results including all infants and results excluding infants with a history of NICU admission ($ps > .05$; see Table 1). Therefore, infants who had NICU stays were included in the analysis, and their subject characteristics were described. Thirty-five of the 141 infants in our study spent time in the NICU. Ten of the 34 infants who were identified with hearing loss spent time in the NICU. Six of those 10 infants were followed through to hearing aid fitting at our facility. Demographic information, age of diagnosis, and fitting information for the 10 infants who spent time in the NICU and were identified with hearing loss are outlined in Table 2. The Colorado Multiple Institutional Review Board approved a waiver of institutional review board oversight for this project.

Statistical Analyses

Because of the methodology of this project, the majority of the analysis is descriptive in nature. When statistical comparisons were made, these were conducted using the Statistical Package for the Social Sciences (SPSS, Version 23, IBM Corporation). Sigma Plot 12.5 (Systat Software) was used to create figures. Independent-samples t tests were used to assess group differences. Bonferroni correction was used to correct for multiple comparisons. Spearman rho was used to assess the relationship between clinic utilization and age-related measures.

Results

The incidence of bilateral permanent hearing loss was 24%. Of these 34 infants, four were diagnosed with auditory neuropathy. As hearing aids are not recommended for infants with auditory neuropathy until behavioral testing confirms functional hearing loss, 30 infants were left to examine how they proceeded with hearing aid fittings. Of the 30 infants with bilateral hearing loss who were recommended to proceed with hearing aids, 70% ($n = 21$) were fitted with hearing aids at this facility. Of the nine infants who did not transition to a hearing aid fitting in our clinic, one moved out of state, two were followed at an outside facility, three were lost to follow-up, two were pending final diagnosis due to a fluctuating conductive hearing loss, and one was deceased.

Age at Diagnostic AEP Sessions

The total number of diagnostic AEP sessions within an individual child was tracked. As stated above, there were 141 infants seen at the first diagnostic evaluation. The average age at first evaluation was 2.23 months ($SD = 1.92$ months). Of infants receiving more than one assessment, 82 infants were seen for a second diagnostic evaluation and the average age was 3.95 months ($SD = 3.45$ months),

Table 1. Mean Joint Committee on Infant Hearing benchmarks for participants with neonatal intensive care unit (NICU) stay included and excluded.

	Infants with NICU stay included (<i>n</i> = 21)	Infants with NICU stay excluded (<i>n</i> = 15)	<i>p</i>
Age at diagnosis (months)	3.06 (<i>SD</i> = 1.58)	2.97 (<i>SD</i> = 1.68)	.155
Age at hearing aid fitting (months)	4.74 (<i>SD</i> = 1.78)	4.27 (<i>SD</i> = 1.60)	.127
Time between diagnosis and fitting (months)	1.68 (<i>SD</i> = 1.49)	1.57 (<i>SD</i> = 1.047)	.405

48 infants were seen for a third diagnostic evaluation and the average age was 6.44 months (*SD* = 4.20 months), 29 infants were seen for a fourth diagnostic session and the average age was 7.20 months (*SD* = 3.01 months), and 16 infants were seen for a fifth diagnostic session and the average age was 10.72 months (*SD* = 4.18 months). No infants required more than five diagnostic sessions to confirm their diagnosis. There was no relationship between infants who spent time the NICU (*n* = 35) and age at any of the five diagnostic sessions (all *ps* > .05 for each diagnostic session).

Degree of Hearing Loss

Once the hearing loss was confirmed, we classified degree of hearing loss based on the better hearing ear as

reported by the managing audiologist: Eight of 34 had mild hearing loss (26–40 dB HL), six of 34 had mild-to-moderate hearing loss (26–55 dB HL), four of 34 had moderate hearing loss (41–55 dB HL), four of 34 had moderate-to-severe hearing loss (56–70 dB HL), two of 34 had severe hearing loss (71–90 dB HL), five of 34 had severe-to-profound hearing loss (71–90+ dB HL), no participants had profound hearing loss (91+ dB HL), four of 34 had auditory neuropathy, and one was inconclusive. Specifically, one infant had a unilateral hearing loss, and it could not be determined if it was truly bilateral due to the middle ear involvement in the other ear. Of the aforementioned babies who were lost to follow-up, all three had a mild degree of hearing loss. Our clinical practice guidelines for the degree of hearing loss are based on those recommended by

Table 2. Patient information for infants with hearing loss in neonatal intensive care unit (NICU).

Patient	Length of NICU stay (in days)	Primary medical diagnoses	Chronological age at hearing loss diagnosis (in months)	Chronological age at hearing aid fitting (in months)
Patient 1	28	Prematurity (32 weeks); twin; in utero drug exposure	4	8.75
Patient 2	130	Prematurity (34 weeks); sepsis; syndrome significant for hearing loss; middle ear fluid requiring medical intervention (pressure equalization tubes)	3	6.5
Patient 3	78	Prematurity (33 weeks), severe intrauterine growth restriction; low birth weight; syndrome significant for hearing loss; hyperbilirubinemia with phototherapy; oxygen support; renal abnormalities; cardiomyopathy	N/A – deceased before confirmed	N/A – deceased
Patient 4	60	Prematurity (28 weeks); twin; low birth weight; chronic lung disease; middle ear fluid, PE tubes; hyperbilirubinemia with phototherapy	4.22	N/A – hearing aid fitting not here
Patient 5	35	Prematurity (33 weeks); congenital CMV; intrauterine growth restriction; hyperbilirubinemia with phototherapy	4.13	5.25
Patient 6	21	Chromosomal microdeletion; cleft palate; hyperbilirubinemia	5.25	6.4
Patient 7	16	Pontine tegmental cap dysplasia; 7th nerve palsy; failure to thrive	0.5	N/A – ANSD
Patient 8	6	Low APGAR scores; head cooling for mild hypoxic–ischemic encephalopathy	2	3.33
Patient 9	4	Late preterm (37 weeks); syndrome significant for hearing loss; intrauterine growth restriction	1.5	5.33
Patient 10	2	Late preterm (37 weeks); hyperbilirubinemia with phototherapy	0.25	N/A – ANSD

Note. Data that could lead to the identification of these infants have been removed due to the timelines being known for this study in order to protect patient identities. For example, rather than listing the specific syndrome, we have listed “syndrome.” PE = pressure equalization; CMV = cytomegalovirus; ANSD = auditory neuropathy spectrum disorder; APGAR = Appearance, Pulse, Grimace, Activity, and Respiration; N/A = not applicable.

the American Speech-Language-Hearing Association (2015) and are listed above in parentheses.

Mean Age at Completion of the JCIH Benchmarks

For each of the 21 patients who transitioned to a hearing aid fitting, we examined the amount of time that elapsed between the age at the diagnosis of their hearing loss ($M = 3.06$ months, $SD = 1.58$ months, range: 0.5–7 months) and the age when the hearing aids were fitted ($M = 4.74$ months, $SD = 1.78$ months, range: 1.5–8.75 months). The average time that elapsed between the diagnosis of hearing loss and hearing aid fitting was 1.68 months ($SD = 1.49$ months, range: 0–5 months).

Are We Meeting the 1-3-6 Guidance?

In our clinical population over a 6-month period, 62% of infants were diagnosed with hearing loss by 3 months of age, and 38% were diagnosed with hearing loss by 2 months of age (see Figure 1). The age at hearing aid fitting was examined in a similar manner: 48% of infants were fitted with hearing aids by 4 months of age, and 14% of infants were fitted by 3 months of age (see Figure 2). The other aspect of the JCIH guidance is the entry into early intervention. Chart review revealed all infants diagnosed with hearing loss were recommended to proceed to early intervention. We were able to track follow-up on this recommendation for 33 of the 34 infants diagnosed with hearing loss. Of the 31 infants diagnosed with hearing loss who were in Colorado to receive services (one family moved to Tennessee, one lived in Wyoming, one infant was deceased), 77% chose to participate in early intervention. It is noted in the Colorado state database if the family declines services. Of the 77% who were enrolled, the average age of enrollment was 4.58 months ($SD = 6.16$ months).

The third guideline assessed was whether infants were fitted with hearing aids within 1 month of diagnosing hearing loss. For our clinical population, 70% of infants were

Figure 2. Percentage of infants fitted with hearing aids at each age (in months). Light gray dotted line represents the current Joint Committee on Infant Hearing (JCIH) recommendation for age at hearing aid fitting (by 4 months, i.e., within 1 month of diagnosis at 3 months of age). Black dotted line, labeled “shifted,” represents the potential future guidance for age of fitting (by 3 months).

fitted within 1 month of their hearing loss being diagnosed (see Figure 3). There was a wide range (0–5 months) in the duration of time that elapsed between the diagnosis and fitting of the hearing aids across the patients. Because of this wide range, we examined several variables that could lead to this. These included NICU stay, the number of cancellations/missed appointments, middle ear involvement, insurance type (private or Medicaid), degree of hearing loss (mild hearing loss or greater than mild degree of hearing loss), and if the infant’s hearing aid consultation was conducted simultaneously with their diagnostic AEP evaluation or separately. Of these factors, three were found to be related to delays in diagnosis and hearing aid fittings: cancellations/missed appointments, milder degree of hearing loss, and middle ear involvement.

The relationship between the age at hearing aid fitting and the number of canceled appointments was significant ($r = .602$, $p < .001$) for increased age at hearing aid

Figure 1. Percentage of infants diagnosed with hearing loss at each age (in months). Light gray dotted line represents the current Joint Committee on Infant Hearing (JCIH) recommendation for age of diagnosis (by 3 months). Black dotted line, labeled “shifted,” represents the potential future guidance for age of diagnosis (by 2 months).

Figure 3. Percentage of infants fitted with hearing aids by amount of time (in months) between diagnosis of hearing loss and hearing aid fitting appointments. Black dotted line represents the current Joint Committee on Infant Hearing recommendation for time elapsed between diagnosis of hearing loss and hearing aid fitting (HAF; by 1 month).

fitting. To further investigate potential factors that led to an increased age at hearing aid fitting, we looked at those babies who moved to hearing aid fittings and compared babies with and without middle ear pathology. Twenty-four percent of babies with permanent bilateral hearing loss reported in this study had middle ear involvement. There was a significant difference, $t(19) = -2.666$, $p = .015$, in the age babies were diagnosed with hearing loss. Furthermore, mean age at hearing aid fitting was 5.88 months ($SD = 1.11$ months) for babies with middle ear pathology, compared to 4.39 months ($SD = 1.82$ months) for babies without middle ear pathology. We also examined if mild hearing loss versus greater degrees of hearing loss was related to age at hearing aid fitting based on previous findings that infants with mild hearing losses are fitted later than those with greater degrees of hearing loss (Dalzell et al., 2000; Walker et al., 2017). A significant inverse relationship was observed ($r = -.469$, $p < .05$). This suggests that infants with a mild hearing loss are fitted later than those with greater degrees of hearing loss.

The final factor we examined that approached significance was the type of visit (AEP paired with hearing aid consult vs. two separate visits) and the impact this had on age at hearing aid fitting appointment. Eight infants had a hearing aid consultation paired with the diagnostic AEP, and 13 had the consultation at a separate visit. The amount of time that elapsed between diagnosis and hearing aid fitting for the group who had a paired visit (AEP evaluation and hearing aid consultation) was 1.17 months, as compared to the group with two separate visits, which showed 1.99 months elapsed between hearing diagnosis and hearing aid fitting. There was not a statistical difference between the two groups ($p = .989$).

Discussion

This project examined if a large metropolitan hospital was meeting the JCIH guidance to determine if a quality improvement project was needed. The findings reported here indicate the next logical steps to execute a quality improvement project. Sixty-two percent of infants were identified with hearing loss by 3 months of age, and 48% were fitted within 1 month of the hearing loss being diagnosed at 3 months of age. When comparing to a 1-2-3 timeline that is currently being discussed in EHDI communities, on average, none of the cutoffs would have been met for this sample. These findings are not unique to our setting; delays in diagnosis of hearing loss and hearing aid fittings found in this project are similar to those from other studies from across the country (Dalzell et al., 2000; Holte et al., 2012; MacNeil et al., 2007; Munoz et al., 2013). Most studies have used parent report to investigate the EHDI process retrospectively, which introduces selection bias as a limitation, with more highly educated Caucasian families being more likely to participate in the study (Holte et al., 2012; MacNeil et al., 2007; Munoz et al., 2013). Families from all socioeconomic levels are seen through the audiology clinics at our facility, and all patients seen during the study

time frame were included in this project, which is slightly different from the studies mentioned above. Overall, 49% of patients seen at our facility utilize Medicaid as their primary insurance. In this project, 56% of the infants diagnosed with hearing loss used publicly funded insurance. The similarity between these two groups suggests that the patients included in this study are a representative sampling of those seen in our department overall. The fact that our findings are similar to those of other studies and that Medicaid status was not significantly related to age at diagnosis or hearing aid fitting suggests outcomes may not vary considerably across different socioeconomic statuses, although further investigation of this topic is warranted. Holte et al. (2012) found a relationship between higher levels of maternal education and earlier first appointments, age at diagnosis, and age at hearing aid fitting. Because of the goal of this project was to determine if we are meeting benchmarking standards, we are unable to comment on maternal level of education and more detailed metrics that may impact timeline completion of the JCIH benchmarks.

This project found that infants were fitted with hearing aids, on average, almost 7 weeks after being diagnosed, rather than within 1 month, as recommended by the JCIH. Seven weeks is similar to findings from Munoz et al. (2013), who noted an average of 2 months between the age of diagnosis and age at hearing aid fitting. Parental report has suggested significant barriers to the hearing aid fitting include cost, acceptance of the need for amplification, and appointment wait times (Munoz et al., 2013). Cost may not be a significant deterrent to hearing aid fittings for many families at our facility because of our large loaner hearing aid bank available for use. However, family acceptance and appointment availability are potential challenges at our facility, as have been noted in other studies (Holte et al., 2012; Munoz et al., 2013).

Barriers to Meeting 1-3-6

The JCIH recommendation of diagnosis by 3 months was thinly missed. Multiple factors may have contributed to this. A first thought may point to the inclusion of infants with a NICU stay. Although the JCIH guideline is the gold standard, it is important to note that it is not realistic for all patients, depending on the additional factors affecting each family/situation. Patients in the NICU often are medically complex and may not be expected to follow the 1-3-6 timeline because of their fragile medical state. Surprisingly, no significant difference in age at diagnosis or hearing aid fitting was noted for infants with NICU stays in this project. This is of particular interest for our purposes of internal auditing, as this hospital has a Level 4 NICU (provides the highest level of specialized neonatal care), and the incidence of hearing loss is known to be higher in the NICU population. These findings differ from those of Dalzell et al. (2000), who found, on average, children in the NICU were identified with hearing loss and fitted with hearing aids later than those who were

not. Our finding may be related to the small number of patients with NICU stays who were followed through to hearing aid fitting ($n = 6$) included in the sample.

Alternatively, the unique structure of inpatient audiology services at our facility may have allowed for more timely access to audiologic services. At this facility, hearing screening, diagnostics, and hearing aid fittings can all be completed while infants are still in the NICU, pending the medical team and family are ready for these steps. The most appropriate testing for inpatients is completed based on newborn hearing screen results and/or medical histories. This can lead to more timely diagnosis of hearing loss. For example, Patient 2 from Table 2 received a diagnostic hearing evaluation as an inpatient due to a syndrome known to be associated with hearing loss, bypassing the newborn hearing screen and allowing for more timely information for the family and medical team. Following the traditional EHDI protocol likely would have led to additional screening/testing. Although the diagnosis was expedited, delays in hearing aid fitting were still seen due to this patient's other medical needs and middle ear involvement. This example provides real-world insights into the challenges seen in serving the NICU population, as well as how adjusting protocols may help to provide more timely services to this complex group. This will help families, the medical team, and therapists understand each patient's needs more fully when developing a care plan. In addition, it may help make the family's life easier by reducing the number of outpatient audiology appointments needed once discharged from the NICU.

In addition to NICU stay, various other factors were investigated that may have contributed to delays in hearing loss diagnosis. Another possible factor is the number of evaluations needed to diagnose the hearing loss. We found hearing loss was diagnosed for 24% of infants in one appointment, 41% in two appointments, and 36% in three or more appointments. These results are similar to those reported by MacNeil et al. (2007), who found 35% diagnosed within one appointment, 28% within two appointments, and 37% in three or more appointments. They cited fussiness of the baby and inconclusive/unclear results as reasons for needing more than one evaluation. Because of the retrospective nature of this project, we cannot comment on these factors. However, finding that presence of middle ear pathology was significantly associated with delayed diagnosis of hearing loss and, in turn, hearing aid fittings, guides our quality improvement project's next steps. This was likely because the resolution of middle ear pathology was sought to confirm the degree of hearing loss and ensure optimal audition with amplification at the time of fitting. Similar findings were noted by Holte et al. (2012), where delays in diagnosis and intervention were reported when otitis media was present. Patient factors such as middle ear pathology are challenging to control for, but being aware of them may aid in more effective partnering with other stakeholders, which is crucial for ensuring these patients receive their final diagnosis and intervention in a timely manner.

Another factor noted to be related to delays in the EHDI process was presence of a mild hearing loss. Walker

et al. (2017) found that children with mild hearing loss were fitted with hearing aids at significantly greater ages than those with more significant degrees of hearing loss. A similar trend was found in this project. The delay between diagnosis of the hearing loss and hearing aid fitting was, on average, more than 3 weeks longer for infants with a mild hearing loss than for those with a greater degree of hearing loss. This led to infants with mild hearing loss being fitted approximately 2 months after diagnosis versus infants with greater degrees of hearing loss who, on average, were fitted just under 5 weeks after diagnosis. This suggests further discussion regarding mild hearing loss is needed within the audiology community to best determine how to counsel and proceed with these patients in a timely fashion.

The final factor found to be related to increased age at hearing aid fitting was the number of canceled/missed appointments. Logically, more canceled/missed appointments led to increased age at diagnosis and fitting. The reasons for the missed/canceled appointments are unknown and merit further examination. Other studies (MacNeil et al., 2007; Munoz et al., 2013) have found the following reasons for missed/canceled appointments: inconvenient appointment times, difficulty in scheduling appointments, appointment wait times, limited sites available (too long travel time to appointment), and family-related barriers such as acceptance of the need for amplification, difficulty finding child care, and not having time off from work.

Reduction in the age at identification and hearing aid fitting could minimize some of these barriers. For example, if the majority of follow-up occurred before the end of maternity leave (typically 12 weeks is allowed based on the Family and Medical Leave Act of 1993), it would reduce the amount of work leave needed for the primary caregiver. Furthermore, parental observation of infants' responses to sounds has been referenced in cases of delayed hearing loss diagnosis (Holte et al., 2012). This is less likely to occur with infants at younger ages, reducing this potential barrier to timely identification and intervention. In addition, as infants get older, the duration of time they sleep decreases. At younger ages, it is more likely the diagnostic process can be completed during natural sleep states with proper instructions for families, potentially reducing the need for multiple appointments due to incomplete test results. Decreasing the number of appointments to final diagnosis could lead to a cascading effect, leading to a reduction in wait times for this type of evaluation. An experienced clinician and good preappointment instructions for parents are also integral in addressing the issues of fussiness and inconclusive/unclear results that were cited by MacNeil et al. (2007).

In order to successfully reduce age at diagnosis, infants must have access to timely appointments. For our sites, one challenge to earlier identification is that we are not a birthing hospital. More specifically, infants' average age at first visit was 2.23 months. Data were not available to evaluate if this delay is due to referral and/or scheduling appointment limitations. Nonetheless, improved collaboration with community stakeholders likely would enhance

parent education and entrance into our system at a younger age.

Limitations

The retrospective nature of this project did not allow us to gather information that may have been useful, such as parental report (e.g., reasons for cancellations), maternal level of education, and prospectively documenting reasons for rescheduled visits (e.g., fussiness, not sleeping, inconclusive results). The small sample size may have led to a lack of statistical power when examining variables such as NICU stay and the impact of combining visits on decreasing age at hearing aid fitting. In addition, we were unable to track the amount of time it took once a family called for an appointment until they were scheduled for an AEP and/or hearing aid consultation, and data were not available regarding configuration of hearing loss.

Conclusions and Future Directions

This project was initiated to examine our current abilities to meet the 1-3-6 guidelines with the goal of promoting improved, long-lasting language outcomes for children with hearing loss (Vohr et al., 2012, 2014). The aim was to identify areas to be addressed by a formal quality improvement project. Similar to other studies, our results revealed the difficulty in meeting the JCIH recommendations for diagnosis by 3 months of age and hearing aid fitting within 1 month of diagnosis. The authors recognize there are areas for improvement in processes to meet the JCIH recommendations, as on average only the early intervention benchmark was achieved in this study. Adjustments in the scheduling process and appointment options have been implemented as a result of this study. The next steps will include strategic steps to decrease the number of visits to confirm a diagnosis when possible and to examine both why these benchmarks are not being met and what can be done to achieve them. Future studies will examine family barriers to timely services in Colorado based on previous studies such as MacNeil et al. (2007) and Munoz et al. (2013). This information could inform scheduling practices, services available to assist families with being able to attend appointments, counseling, and vision for alternative service provision. Alternative service provision may include expansion of current locations, partnering with local audiologists in more rural areas of the state to provide pediatric training, telehealth, and/or traveling audiology services. The impact of socioeconomic status and the presence of additional medical needs will also be evaluated more thoroughly and in a larger sample to determine if results seen in this project hold with a larger sample size and use of different metrics for these variables. Finally, we plan to examine the stress levels between families who can complete the majority of visits before returning to work versus those who are identified and fitted with hearing aids after returning to work.

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References

- American Academy of Audiology.** (2012). *Audiologic guidelines for the assessment of hearing in infants and young children*. Retrieved from https://audiology-web.s3.amazonaws.com/migrated/201208_AudGuideAssessHear_youth.pdf_5399751b249593.36017703.pdf
- American Speech-Language-Hearing Association.** (2015). *Type, degree, and configuration of hearing loss*. Rockville, MD: Author.
- Centers for Disease Control and Prevention.** (2012). *Summary of 2009 National CDC EHDI data*. Retrieved from <http://www.cdc.gov/ncbddd/hearingloss/data.html>
- Colorado Department of Health Policy & Financing.** (2017). *Child Health Plan Plus (CHP+)*. Retrieved from <https://www.colorado.gov/pacific/hcpf/child-health-plan-plus>
- Colorado Department of Public Health and Environment.** (2004). *Colorado infant hearing advisory committee: Guidelines for infant hearing screening, audiologic assessment, and early intervention*. Denver, CO: Author.
- Coplan, J.** (1987). Deafness: Ever heard of it? Delayed recognition of permanent hearing loss. *Pediatrics*, 79(2), 206–213.
- Dalzell, L., Orlando, M., MacDonald, M., Berg, A., Bradley, M., Cacace, A., . . . Prieve, B.** (2000). The New York state universal newborn hearing screening demonstration project: Ages of hearing loss identification, hearing aid fitting, and enrollment in early intervention. *Ear and Hearing*, 21(2), 118–130.
- Family and Medical Leave Act, 29 U.S.C. §§ 2601–2654. (1993).
- Folsom, R. C., Widen, J. E., Vohr, B. R., Cone-Wesson, B., Gorga, M. P., Sininger, Y. S., & Norton, S. J.** (2000). Identification of neonatal hearing impairment: Recruitment and follow-up. *Ear and Hearing*, 21(5), 462–470.
- Halpin, K. S., Smith, K. Y., Widen, J. E., & Chertoff, M. E.** (2010). Effects of universal newborn hearing screening on an early intervention program for children with hearing loss, birth to 3 yr of age. *Journal of the American Academy of Audiology*, 21(3), 169–175.
- Harrison, M., & Roush, J.** (1996). Age of suspicion, identification, and intervention for infants and young children with hearing loss: A national study. *Ear and Hearing*, 17(1), 55–62.
- Holden-Pitt, L., & Diaz, J. A.** (1998). Thirty years of the annual survey of deaf and hard-of-hearing children & youth: A glance over the decades. *American Annals of the Deaf*, 143(2), 71–76.
- Holte, L., Walker, E., Oleson, J., Sprattford, M., Moeller, M. P., Roush, P., . . . Tomblin, J. B.** (2012). Factors influencing follow-up to newborn hearing screening or infants who are hard of hearing. *American Journal of Audiology*, 21(2), 163–174.
- Jerger, J. F., & Hayes, D.** (1976). The cross-check principle in pediatric audiology. *Archives of Otolaryngology*, 102, 614–620.
- Joint Committee on Infant Hearing.** (2000). Year 2000 position statement: Principles and guidelines for early hearing detection and intervention programs. *Pediatrics*, 106(4), 798–817.
- Joint Committee on Infant Hearing.** (2007). Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs. *Pediatrics*, 120(4), 898–921.

- Kennedy, C. R., McCann, D. C., Campbell, M. J., Law, C. M., Mullee, M., Petrou, S., . . . Stevenson, J. (2006). Language ability after early detection of permanent childhood hearing impairment. *The New England Journal of Medicine*, 354, 2131–2141.
- MacNeil, J. R., Liu, C.-L., Stone, S., & Farrell, J. (2007). Evaluating families' satisfaction with early hearing detection and intervention services in Massachusetts. *American Journal of Audiology*, 16, 29–56.
- Marcin, J. P., Schembri, M. S., He, J., & Romano, P. S. (2003). A population-based analysis of socioeconomic status and insurance status and their relationship with pediatric trauma hospitalization and mortality rates. *American Journal of Public Health*, 93(3), 461–466.
- Moeller, M. P. (2000). Early intervention and language development in children who are deaf and hard of hearing. *Pediatrics*, 106(3), e43. <https://doi.org/10.1542/peds.106.3.e43>
- Moeller, M. P., Eiten, L., White, K., & Shisler, L. (2006). Strategies for educating physicians about newborn hearing screening. *Journal of the Academy of Rehabilitative Audiology*, 39, 11–32.
- Moeller, M. P., White, K. R., & Shisler, L. (2006). Primary care physicians' knowledge, attitudes, and practices related to newborn hearing screening. *Pediatrics*, 118(4), 1357–1370.
- Munoz, K., Blaiser, K., & Barwick, K. (2013). Parent hearing aid experiences in the United States. *Journal of the American Academy of Audiology*, 24(1), 5–16.
- Ruben, R. J. (1997). A time frame of critical/sensitive periods of language development. *Acta Oto-Laryngologica*, 117(2), 202–205.
- Sininger, Y. S., Grimes, A., & Christensen, E. (2010). Auditory development in early amplified children: Factors influencing auditory-based communication outcomes in children with hearing loss. *Ear and Hearing*, 31(2), 166–185. <https://doi.org/10.1097/AUD.0b013e3181c8e7b6>
- Sininger, Y. S., Martinez, A., Eisenberg, L., Christensen, E., Grimes, A., & Hu, J. (2009). Newborn hearing screening speeds diagnosis and access to intervention by 20–25 months. *Journal of the American Academy of Audiology*, 20(1), 49–57.
- Spivak, L., Sokol, H., Auerbach, C., & Gershkovich, S. (2009). Newborn hearing screening follow-up: Factors affecting hearing aid fitting by 6 months of age. *American Journal of Audiology*, 18, 24–33.
- Stein, L. K., Jabaley, T., Spitz, R., Stoakley, D., & McGee, T. (1990). The hearing-impaired infant: Patterns of identification and habilitation revisited. *Ear and Hearing*, 11(3), 201–205.
- Tomblin, J. B., Harrison, M., Ambrose, S. E., Walker, E. A., Oleson, J. J., & Moeller, M. P. (2015). Language outcomes in young children with mild to severe hearing loss. *Ear and Hearing*, 36, 76S–91S.
- Tomblin, J. B., Oleson, J. J., Ambrose, S. E., Walker, E., & Moeller, M. P. (2014). The influence of hearing aids on the speech and language development of children with hearing loss. *JAMA Otolaryngology—Head & Neck Surgery*, 140(5), 403–409.
- Vohr, B., Jodoin-Krauzyk, J., Tucker, R., Johnson, M. J., Topol, D., & Ahlgren, M. (2008). Early language outcomes of early-identified infants with permanent hearing loss at 12 to 16 months of age. *Pediatrics*, 122(3), 535–544.
- Vohr, B., Jodoin-Krauzyk, J., Tucker, R., Topol, D., Johnson, M., Ahlgren, M., & St. Pierre, L. (2011). Expressive vocabulary of children with hearing loss in the first 2 years of life: Impact of early intervention. *Journal of Perinatology*, 31, 274–280.
- Vohr, B., St. Pierre, L., Topol, D., Jodoin-Krauzyk, J., Bloome, J., & Tucker, R. (2010). Association of maternal communicative behavior with child vocabulary at 18–24 months for children with congenital hearing loss. *Early Human Development*, 86, 255–260.
- Vohr, B., Topol, D., Girard, N., St. Pierre, L., Watson, V., & Tucker, R. (2012). Language outcomes and service provision of preschool children with congenital hearing loss. *Early Human Development*, 88, 493–498.
- Vohr, B., Topol, D., Watson, V., St. Pierre, L., & Tucker, R. (2014). The importance of language in the home for school-age children with permanent hearing loss. *Acta Paediatrica*, 103(1), 62–69.
- Walker, E. A., Spratford, M., Ambrose, S. E., Holte, L., & Oleson, J. (2017). Service delivery to children with mild hearing loss: Current practice patterns and parent perceptions. *American Journal of Audiology*, 26, 38–52.
- White, K. R. (2003). The current status of EHDI programs in the United States. *Mental Retardation and Developmental Disabilities Research Reviews*, 9(2), 79–88.
- Yoshinaga-Itano, C., Coulter, D., & Thomson, V. (2000). Infant hearing impairment and universal hearing screening. *Journal of Perinatology*, 20, S131–S136.
- Yoshinaga-Itano, C., Sedey, A. L., Coulter, D. K., & Mehl, A. L. (1998). Language of early- and later-identified children with hearing loss. *Pediatrics*, 102(5), 1161–1171.
- Yoshinaga-Itano, C., Sedey, A. L., Wiggins, M., & Chung, W. (2017). Early hearing detection and vocabulary of children with hearing loss. *Pediatrics*, 140(2), 1–10.