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Implementing a Hearing Screening Readiness Assessment Tool for Preterm and Term Neonates in the Newborn Intensive Care Unit: A Pilot Project

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Abstract
Newborn intensive care unit (NICU) patients are at risk for hearing loss. Early detection mitigates consequences of speech and language delay. The Joint Committee on Infant Hearing (JCIH, 2019) recommends hearing screening (HS) on all infants by 1 month of age. Routinely, hearing screening is performed around time of NICU discharge, oftentimes beyond JCIH recommendations. Automated auditory brainstem response (AABR) screening can be performed once an infant reaches 32 to 34 weeks corrected gestational age. Our project aimed to reduce HS delay among NICU infants. We created and implemented a HS assessment tool defining gestational age (GA) and medical stability parameters for initial HS. Data were compared between 100 infants pre-implementation and 325 infants post-implementation. After implementation, infants had HS performed 4 days earlier in days of life ($p = 0.28$) and 4 days earlier, prior to discharge ($p < 0.0001$). Infants born before 34 weeks GA had HS performed 11 days of life earlier ($p = 0.02$) and 14 days earlier prior to discharge ($p < 0.0001$). More preterm infants completed HS at less than 1 month of age (34% vs 61%, $p = 0.06$). Earlier HS is associated with a 6.3% increase in false positive screens among premature neonates, requiring repeat screening. Because evidence suggests the tool may promote earlier HS for preterm infants, additional work on optimizing the HS technique is needed to lower false positive results.

Keywords: hearing screening, preterm, neonates, neonatal intensive care unit, assessment tool

Acronyms: AAP = American Academy of Pediatrics; AABR = automated auditory brainstem response; EHDI = Early Hearing Detection and Intervention; GA = gestational age; HS = hearing screening; NICU = Newborn Intensive Care Unit; QI = quality improvement

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Hearing loss is one of the most common congenital birth conditions. The occurrence rate for sensorineural hearing loss is about 1.7 per 1,000 (0.17%) live births in the United States (Centers for Disease Control and Prevention, 2021) and up to 24% among high-risk neonates admitted to the Newborn Intensive Care Unit (NICU; Berg et al., 2005). NICU patients are at higher risk for hearing loss due to prematurity, sepsis, ototoxic medication exposure, congenital viral infections, genetic syndromes, congenital craniofacial anomalies, hyperbilirubinemia, hypoxia, and noise exposure from life-saving medical support (Wroblewska-Seniuk et al., 2016). Early detection and intervention may greatly improve long-term neurodevelopmental outcomes for deaf/hard of hearing infants (Joint Committee on Infant Hearing, 2019).

The Joint Committee on Infant Hearing (JCIH), which includes representation from the American Academy of Pediatrics (AAP), supports Early Hearing Detection and Intervention (EHDI) guidelines (JCIH, 2019). The EHDI 1-3-6 goals are to have all infants receive initial hearing screening by 1 month of age, a diagnostic evaluation no later than 3 months (if initial HS warrants additional testing), and early intervention no later than 6 months of age (if otologic evaluation confirms a deaf/hard of hearing outcome). JCIH 2019 guidelines support intervention as early as 3 months if possible.

Meeting EHDI guidelines can be challenging in the NICU population. It may not be practical to perform initial HS on NICU infants by 1 month of age. In addition to prematurity, NICU infants may be too critically ill to tolerate a HS

or the life-supporting medical equipment may interfere with the instrumentation required for hearing screening. The JCIH recommends HS for NICU infants as soon as they are medically stable (JCIH, 2019). However, JCIH does not define medical stability in respect to the NICU population. There are no specific recommendations on what parameters define medical stability, and there is no consensus on how to determine optimal timing for newborn HS in regard to NICU infants. Evidence shows that the automated auditory brainstem response (AABR) screen can be reliably performed at 32 to 34 weeks corrected GA (Wroblewska-Seniuk et al., 2016), yet HS is often performed immediately before NICU discharge and greater than 30 days of age (Chung et al., 2019; Patel et al., 2018).

The goal of this quality improvement (QI) project was to develop a HS readiness assessment tool aimed at improving the timing of initial HS for NICU patients. The specific aim was to reduce the age at which initial HS is performed.

Method

Setting/Population

Our QI project was conducted at a 52-bed level III NICU located in Salt Lake City, Utah. This NICU is a major birthing hospital for the Salt Lake region, as well as a referral center for four neighboring states. This unit provides care for critically ill newborns with gestational ages ranging from approximately 23 weeks to over 40 weeks, with more than 600 NICU admissions annually. The study population included all preterm and term NICU patients who required hearing screening. The study excluded infants who were being discharged home on comfort care/hospice, died prior to HS eligibility, or who were being transferred to a different facility or lower level of care.

Intervention

To achieve this specific aim, the project underwent three phases. In Phase 1, a retrospective chart review was conducted on all NICU patients with HS done 3 months prior to study implementation. We evaluated the timing and GA of these NICU patients upon receiving initial hearing screening. In Phase 2, a multidisciplinary team including audiologists, developmental care specialists, nurses, and nurse practitioners was formed. The team developed an updated HS protocol based on current literature and expert opinion. The team considered criteria eligibility for HS, parameters of medical stability, and medical interventions or factors that may interfere with HS results.

The followings criteria were used to evaluate HS readiness. The neonate:

1) Is at least 34 weeks corrected gestational age
2) Maintains stable body temperature without external heat source
3) Requires minimal or no respiratory support
4) Has no critical self-supporting lines and/or drains; excluding feeding tubes
5) Has completed aminoglycoside treatment course (if needed)
6) Is not receiving medication treatment for neonatal abstinence syndrome
7) Tolerates routine care without decompensation

Initially, we attempted to integrate the above criteria as a function of the electronic health record; however due to constraints associated with the COVID-19 pandemic, the informatics department was unable to coordinate this in a timely manner. An alternative paper HS readiness assessment tool was created based on the above criteria (Appendix). This readiness tool was used to alert NICU providers when an infant met criteria for initial hearing screening.

In Phase 3, NICU providers received mandatory education on the new screening tool/guideline via an online presentation. Upon completion of training, the HS readiness assessment tool was implemented in the NICU and follow up outcome data were collected to evaluate tool effectiveness. The team set up a process to alert audiology to perform HS, as well as electronic documentation of HS results. Once a provider deemed an infant eligible for HS via the assessment tool, the form was placed in a pre-determined box for audiology. Audiology would then confirm readiness and perform HS per the new guideline, documenting HS results in the electronic health record. Weekly educational reminders were provided to promote continued awareness of the screening tool.

Measures

Outcome measures included the day of life at which initial HS was performed, the number of days HS was done prior to discharge, the proportion of HS performed prior to Day of Life 30, and the days between infants meeting HS eligibility and HS being performed. False positive rates were evaluated as a balancing measure in relation to performing earlier HS, particularly in the preterm population. Provider use of the HS readiness assessment tool was monitored as a process measure to determine if implementation improved outcomes.

Analysis

Data were compared between 3 months pre-implementation (July 2020–early October 2020) and 9 months (mid October 2020–July 2021) post-implementation. Descriptive statistics of median and interquartile ranges were used to describe demographic data including birthweight, GA, and length of stay. A subgroup comparative analysis of neonates who were born at less than 34 weeks GA was performed. Outcome measures were compared between the pre- and post-implementation period. The Mann-Whitney U-test, also known as a Wilcoxon rank-sum test, and Fisher's exact test were used for ordinal data or continuous data that were not normally distributed. A two-sided *p*-value of less than 0.05 was considered statistically significant. Statistical analysis was performed using GraphPad Prism Version 9.2.0 for MacOs (GraphPad Software, La Jolla, California, USA, http://www.graphpad.com).

Ethical Considerations

Institutional review board approval was obtained from the University of Utah. The committee approved a waiver of informed consent as it was a QI project with minimal risk to patients.

Results

Following implementation of the tool, informal feedback was gathered during weekly multidisciplinary rounds regarding the new HS process and the HS tool. Practitioners verbalized a better understanding of HS readiness and an increase in knowledge regarding current HS recommendations, although this feedback was not quantified.

Baseline data was gathered from 100 NICU patients who had HS performed within the 3-month period prior to QI project implementation. During the post-implementation period, 325 NICU patients had HS done within a 9-month period. The neonates' demographic characteristics were not significantly different between the two periods (Table 1). After study implementation, initial HS was performed 4 days earlier in age for all neonates, although this was not statistically significant (15 vs. 11 days, $p = 0.28$; Table 2). However, the number of days HS was performed prior to discharge improved from 3 days to 7 days earlier ($p < 0.0001$) with the length of stay not being significantly longer among the post-implementation population (Table 2).

Table 1

Demographic Characteristics of Neonates During the Pre- and Post-Implementation Periods

	Neonates of All Birth GA				***Neonates of Birth GA < 34 Weeks***			
	Pre (*n* = 100)	**Post (*n* = 325)**	**Wilcoxon statistic**	***p* value***	**Pre (*n* = 29)**	**Post (*n* = 126)**	**Wilcoxon statistic**	***p* value***
BW (kg), median (IQR)	2.5 (1.8–3.3)	2.4 (1.8–3.1)	15030	0.256	1.5 (1.2–1.9)	1.7 (1.4–2.0)	2065	0.277
GA (wk), median (IQR)	36 (33–38)	35 (33–38)	14727	0.156	32 (29–33)	32 (30–33)	1942	0.599
LOS (d), median (IQR)	19 (8–32)	21 (10–43)	17906	0.123	41 (30–74)	47 (30–67)	1839	0.958

Note. BW = birthweight; d = days; GA = gestational age; IQR = interquartile range; kg = kilogram; LOS = length of stay; *n* = number in category; Pre = pre-implementation period; Post = post-implementation period; wk = weeks. *Wilcoxon rank sum test.

Table 2

Outcomes for Neonates During the Pre- and Post-Implementation Periods

	Neonates of All Birth GA				***Neonates of Birth GA < 34 Weeks***			
	Pre (*n* = 100)	**Post (*n* = 325)**	**Wilcoxon statistic**	***p* value**	**Pre (*n* = 29)**	**Post (*n* = 126)**	**Wilcoxon statistic**	***p* value**
Percentage of HS was done at < 31 DOL (%)	80%	84%	N/A	0.45+	34%	61%	N/A	0.06+
DOL when HS was done (d), median (IQR)	15 (6–27)	11 (7–23)	15161	0.311*	37 (24–65)	26 (15–40)	1202	0.004*
Days between HS was done and NICU discharge (d), median (IQR)	3 (2–4)	7 (2–18)	22275	< 0.001*	4 (3–8)	18 (11–26)	3141	< 0.0001*

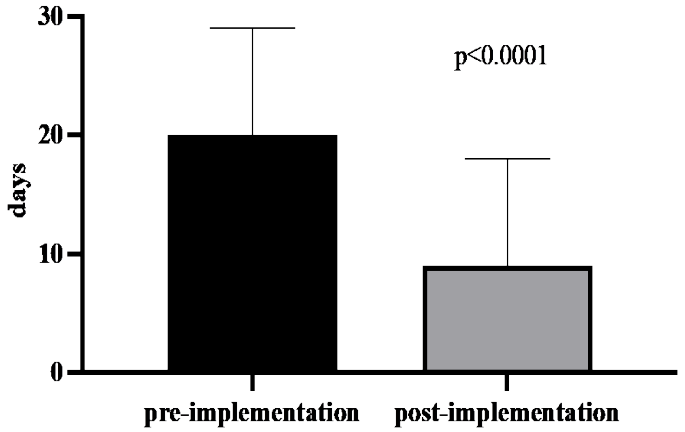
Note. d = day; DOL = days of life; GA = gestational age; HS = hearing screening; IQR = interquartile range; *n* = number in category; Pre = pre-implementation period; Post = post-implementation period. *Wilcoxon rank sum test; +Fisher's exact test.

The subgroup analysis showed significant impact among neonates who were born at less than 34 weeks GA. Compared to the pre-implementation period, there was an increased percentage of HS being done by 1 month of age, meeting the JCIH recommended goal, (34% vs. 61%, $p = 0.06$) in the post-implementation period. During the post-implementation period, preterm neonates had initial HS done 11 days earlier ($p = 0.02$) and 14 days earlier prior to discharge ($p < 0.0001$; Table 2). HS was also done 11 days sooner once corrected GA eligibility was met ($p < 0.0001$; Figure 1).

Performing HS at an earlier GA increased the risk of false positive results. During the pre-implementation period, 3 out of 100 neonates (3%) had an abnormal AABR hearing screen. They all had confirmed hearing loss and were all born at over 34 weeks gestational age. The false positive rate was 0%. During the post-implementation period, 25 out of 325 neonates (7.7%) failed the first AABR, 15 of these infants had confirmed hearing loss on repeated testing. The prevalence of hearing loss in this cohort was 4.6%, which was not significantly different compared to the pre-implementation period ($p = 0.58$). Of the infants

Figure 1

Pre and Post Data



Note. Days between when hearing screen was performed after reaching corrected gestational age of 34 weeks, compared to the pre-implementation (n = 29) and post-implementation period (n = 126). 20 vs 9 days, $p < 0.0001$.

who failed the first AABR, ten passed the repeat HS. The false positive rate of the initial HS was 3% (10/325) higher than the pre-implementation period (p = 0.08). The HS sensitivity and specificity were 100% and 96.8% respectively during the post-implementation period. The majority of the false positive cases was found among neonates who were born at less than 34 weeks gestational age (8/126, 6.3%).

The paper HS assessment tool usage was only tracked for the first three months during the nine month post-implementation period. During this time period the paper HS assessment tool was only used for 55% of eligible patients. Paper tool usage was not tracked for the remainder of the post-implementation period due to low adoption rates among caregivers.

Discussion

NICU infants experience HS delay more often compared to their non-NICU peers. Previous studies suggest that creating specific clinical guidelines for the timing of early hearing screening in NICU infants may be warranted to improve the delay NICU patients experience in regards to initial HS (Sapp et al., 2020).

An extensive literature review was performed prior to project implementation; to our knowledge this is the first study in which a HS readiness assessment tool was developed to define GA and medical stability criteria for HS readiness in the NICU population. Our QI project promoted HS to be done earlier to meet the JCIH recommended HS goal. The major impact was seen among neonates born before 34 weeks GA by significantly reducing the age at which initial HS was performed. HS was also done sooner once GA eligibility was met. Earlier initial HS is the most important outcome of this project. Earlier screening creates more time between HS and NICU discharge. The benefit of extra time allows for repeat assessment and adequate referral set up as needed. The extra time also allows for the infant's caregiver(s) to process a new diagnosis, begin education regarding hearing loss, and further develop a relationship with the audiologist/audiology team, hopefully reducing loss to follow-up post discharge. These benefits may directly and/or indirectly translate into improved linguistic and developmental outcomes. Longitudinal studies have shown that timely referral to early intervention systems improves spoken and signed language development of deaf/hard of hearing newborns (Yoshinaga-Itano, 2014).

False positive rates were found to be increased in the post-implementation group, especially for those born at less than 34 weeks (p = 0.08). Prior studies in full-term infants have shown that the false positive rate of initial HS was 3.9% and repeated HS prior to discharge decreased the false positive rate to less than 1% (Clemens & Davis, 2001). The initial HS false positive was 6.3% among preterm neonates. More preterm neonates required repeat HS prior to discharge and passed the test subsequently. The common reason of the failed initial screening may be contributed to middle ear issues (Clemens et al., 2000). Middle ear effusion is even more prevalent in NICU patients, as they tend to be in the supine position for long periods of time. They may be receiving nasogastric tube feedings and/or humidified respiratory support. Another reason for our higher rate of false positive results may be due to neonatal prematurity. The peripheral hearing system matures with gestational age (Pujol et al., 1991). There is a risk of introducing false results by performing HS earlier in gestational age. Prior studies have shown that the hearing threshold decreased with increased gestational age postnatally (Pujol et al., 1991). The hearing threshold of extreme preterm neonates decreased from 28 dB at 28 weeks corrected GA to 13 dB at 42 weeks corrected GA, a rate of 1 dB/week (Jiang et al., 2015). When initial HS is performed earlier in GA, it becomes more likely that a preterm neonate may fail. Van Straaten and colleagues (2001) have shown that AABR screening can be reliably performed at 32 to 34 weeks corrected gestational age with a threshold setting of 35 dB, as adapted by our unit protocol. Because the risk of false positive HS results exists with screening at an earlier gestational age, we chose to perform initial screening at 34 weeks corrected GA, as opposed to 32 weeks corrected GA, in hopes of reducing the amount of false positive results.

A false positive HS result may increase parental anxiety and process costs; however a survey has shown no significant long-term or detrimental emotional impact on parents of infants with false positive HS (Clemens et al., 2000). Parental anxiety could be reduced with improved understanding regarding the infant hearing screening process (Clemens et al., 2000). We feel the benefit of earlier screening likely outweighs the risk of false positive HS as it allows the audiologist more time to properly support parents, repeat HS prior to discharge, and coordinate referral/offer interventions as needed (Clemens et al., 2000).

Implementation success was attributed to the providers' participation and education provided. Similar to prior literature, timing of initial HS greatly improved after

implementing an updated HS process and educating providers to identify patients eligible for early screening (Patel et al., 2018). The HS readiness assessment tool also improved workflow of the audiologists' by alerting them to eligible neonates, allowing the team to better prioritize NICU neonates for HS. The cost of this project was minimal; most of that cost surrounding the project was attributed to creating time for staff education.

Limitations

Major barriers in implementing an updated HS guideline were communication and education. Specifically, there was a lack of understanding that AABR screening can be reliably performed at approximately 32 to 34 weeks corrected gestation (Van Straaten et al., 2001). Additionally, the HS readiness assessment tool was unable to be integrated into the electronic health record in a timely manner due to constraints associated with the COVID-19 pandemic. A paper screening tool was developed as an alternative, but use was poor. These barriers were addressed with education regarding the new HS guideline via PowerPoint presentation and weekly educational reminders provided to promote continued awareness of the new protocol. Providers were verbally or electronically reminded via email to use the HS readiness assessment tool on a weekly basis. Despite consistent reminders for using the paper tool, the usage rate remained low. We speculate that our improved outcomes were due to verbal communication and education rather than the paper tool usage. Integration of an electronic version of the HS assessment tool would likely increase use and decrease dependence on the project team leader's verbal reminder for long-term sustainability.

Conclusion

Timely identification of hearing loss in NICU patients is important to improve long-term neurodevelopmental outcomes. The project was likely the first to itemize HS eligibility. The HS readiness assessment tool improved timeliness of initial HS in the NICU, particularly for the preterm population. The project would likely be more sustainable by integrating the HS assessment tool into the electronic medical record system. Although NICU HS readiness guidelines may benefit preterm neonates, further study is needed to optimize HS techniques to lower false positive screens.

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HEARING SCREENING ASSESSMENT TOOL

GESTATIONAL AGE

+ Is the infant as least 34 weeks corrected gestational age? **YES □ NO □**

It is not recommended to conduct newborn hearing screening before the infant is 34 weeks gestational age related to immaturity of the auditory nervous system. It is appropriate to evaluate hearing screening readiness at 34 weeks gestational age.

THERMOREGULATION

+ Is the infant thermodynamically stable? **YES □ NO □**

Newborn hearing screening should not be conducted on infants requiring an incubator or radiant heat to maintain body temperature. Once an infant has proved to be thermodynamically stable in an open crib, it is appropriate to evaluate readiness for newborn hearing screening.

RESPIRATORY SUPPORT

+ Is the infant requiring minimal or no oxygen therapy? **YES □ NO □**

Infants placed on ventilators, CPAP, or high-flow nasal cannula are not candidates for hearing screen, these respiratory modalities may interfere with the screening process. It is appropriate to screen infants who are stable on regular nasal cannula, low-flow nasal cannula, or not requiring oxygen therapy.

LINES and/or DRAINS

+ Does the infant have any critical lines and/or drains? **YES □ NO □**

Infants requiring critical lines or drains for advanced medical support are not considered stable. Examples of critical lines include: umbilical catheters, chest tubes, gastric decompression tubes, etc. If an infant requires a surgical procedure, screening should be performed post-operatively, once the infant is medically stable. However, it is appropriate to screen infants requiring gastric tube placement prior to surgery.

NUTRITION

+ Has the infant reached full enteral feeds? **YES □ NO □**

Infants requiring parenteral nutrition are not candidates for screening in the UUMC NICU. Infants should be receiving full enteral feeds to be considered for a newborn hearing screening. It is acceptable to conduct newborn hearing screening on infants receiving feeds via nasogastric tube. It is also acceptable to conduct screening on infants with stable gastric tubes.

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MEDICATIONS

+ Is the infant receiving ototoxic medications? **YES □ NO □**

Newborn hearing screening should be deferred for infants requiring aminoglycoside administration for more than 5 days. It is appropriate to evaluate hearing screening readiness after the 5-day course has been completed. If an infant does not require a 5-day course of aminoglycoside administration, hearing screening readiness can be evaluated as infant condition warrants. If questions arise regarding the ototoxic potential of other medications an infant may be receiving, consult pharmacy and audiology.

+ Is the infant being treated for Neonatal Abstinence Syndrome (NAS)? **YES □ NO □**

Neonatal abstinence syndrome can cause central nervous system hyperirritability, which may interfere with the hearing screening process. Infants being treated for NAS should not be considered candidates for newborn hearing screening during a period of severe withdrawal. It is appropriate to screen NAS infants once Neonatal Withdrawal Index (NWI) scores are trending down, and the infant is consolable.

PHYSIOLOGICAL STABILITY

+ Does the infant tolerate assessment/cares? **YES □ NO □**

Any baby who decompensates with care should not be considered stable. Decompensation can be defined as, but not limited to the following: apnea, bradycardia, oxygen desaturations, tachypnea, and tachycardia. It is appropriate to evaluate hearing screening readiness on infants who tolerate assessment without experiencing physiological instability.

AS SOON AS YOU FEEL AN INFANT MEETS THE ABOVE REQUIREMENTS, PLEASE PLACE A PATIENT LABEL ON THE FRONT OF THIS SHEET AND RETURN THIS SCREENING TOOL TO AUDIOLOGY VIA THE DESIGNATED BIN LOCATED IN THE NNP OFFICE. AUDIOLOGY WILL PERIODICALLY COLLECT THESE ASSESSMENTS AND BEGIN EVALUATIONS.

If you have any questions or concerns regarding this tool please contact McKenzie Blatt, NNP or Adrienne Johnson, AuD.

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