

NEURODEVELOPMENTAL EVALUATION IN A NEONATAL FOLLOW UP CLINIC

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Dedication and Acknowledgements

I dedicate my DNP project to the patients and families that I have had the honor of caring for over many years in my practice as a pediatric nurse practitioner. I am so grateful for all that I have learned from you. I would like to thank my husband, Jeff, and my daughters, Eve and Liza, for supporting me during this journey. There have certainly been sacrifices made by each of you so that I could complete my dream of earning my doctorate. I am forever thankful to Dr. Michelle Chiu for hiring me in her neonatal follow up clinic and for encouraging me every step of the way during the past 2 years. To the clinic physical therapists and speech therapists, thank you for teaching me so much about child development and thank you for all the hours you put into this project. Thank you to Professor Amita Mittal for lending her expertise in statistics for the data analysis. A heart-felt thank you goes to Dr. Angela Kabbe for her knowledge, patience, understanding, and mentorship during this entire process.

Abstract

Background: Thorough neurodevelopmental evaluation of high-risk infants is important in the identification of neurodevelopmental delays. **Purpose:** The purpose of this project was to determine if using the Hammersmith Infant Neurological Examination (HINE) as an adjunct tool for neurodevelopmental evaluation would improve identification of neurodevelopmental delays. **Methods:** 105 patients in a neonatal follow up clinic were included in the project. Patient ages were 3 months to 12 months. Patients included preterm and term gestational ages. 74 patients were evaluated using the Bayley Scales of Infant Development fourth edition (BSID IV). 31 patients were evaluated using the BSID IV and the HINE. **Results:** Adding the HINE did not show a significant improvement in the identification of developmental delays and did not show a significant increase in qualification for a referral for intervention for delays. In the group evaluated using both the HINE and the BSID, there was a significant association between the BSID scores and the HINE scores. The HINE identified abnormalities and a risk for delay in some of the patients in this group while the BSID alone did not show delays. **Recommendations and Conclusion:** Using the HINE in addition to the BSID in neurodevelopmental evaluation can be useful in identifying early risk for neurodevelopmental delays in the high-risk infant population. The HINE and the BSID provide important information regarding developmental progress. Using only one tool in developmental evaluation may miss early signs of delays.

Background and Significance

The rate of preterm birth, defined as birth less than 37 weeks' gestation, is rising in the United States. In 2018, 10.02% of births were classified as preterm. This is an increase from 9.57 % in 2014 (Martin et al., 2019). Advances in neonatology have increased the survival rate of preterm infants. With increases in survival, there are increases in associated morbidities and risk for delays in development (McGowan & Vohr, 2019). Because of these risks, infants hospitalized the Neonatal Intensive Care Unit (NICU) require close follow up care after NICU discharge. These infants can be medically complex and often require the expertise of a multidisciplinary team for post- discharge medical and developmental surveillance (Voller, 2018). In addition to prematurity, other diagnoses managed in the NICU carry risk factors for neurodevelopmental delays. Examples of some high-risk diagnoses include hypoxic ischemic encephalopathy, neonatal abstinence syndrome, and genetic syndromes (Orton et al., 2018).

High risk Follow-Up Clinics (HRFC), or neonatal follow up clinics, provide continued medical and developmental monitoring of high-risk infants. Neurodevelopmental delays include cognitive delays, motor skill delays, and language delays (Orton et al., 2018). The American Academy of Pediatrics (AAP) published a policy statement regarding the follow up of high-risk neonates after hospital discharge. The AAP policy calls for continued incremental evaluation of neurodevelopment in high risk neonates (Committee on Fetus and Newborn, 2008). Preterm infants are at higher risk than term infants for neurodevelopmental delays (Voller, 2018). Medical conditions associated with prematurity, such as intraventricular hemorrhage, periventricular leukomalacia, necrotizing enterocolitis, chronic lung disease, and surgical procedures are risk factors for delays (Orton et al., 2018). Preterm infants less than 32 weeks'

gestation and those infants less than 1500 grams at birth are considered at the highest risk for delays (Orton et al., 2018).

Clinicians in neonatal follow up clinics rely on screening tools for assessment of neurodevelopmental delays. Screening tools provide information regarding general developmental milestone achievement and neurological development (Orton et al., 2018). Results from general developmental screening and neurological screening provide important information about neurodevelopmental progress (Morgan et al., 2019).

The Bayley Scales of Infant Development (BSID) is most commonly used in neonatal follow up to evaluate general developmental milestone achievement (Anderson & Burnett, 2017). Multiple editions of the BSID are currently available for use. The neonatal follow up clinic project setting currently uses the BSID IV, the most recent edition of the BSID. Findings in the literature suggest that the BSID, especially the third edition, may overestimate the degree of cognitive and motor functioning, therefore resulting in an underestimate of neurodevelopmental delay (Anderson & Burnett, 2017; Pascal et al., 2018). The BSID IV was released in 2020. No studies are available currently to review clinician experience with the BSID IV and its estimation of motor development compared to the BSID III.

The Hammersmith Infant Neurological Evaluation (HINE) is a neurological assessment used in neonatal follow up care (Maitre et al., 2016). The HINE is divided into categories assessing neurological development including tone, posture, cranial nerves, movement, and reflexes. Using the HINE for neurological evaluation can give the examiner needed information for the prediction of motor outcomes possibly not provided by the BSID. The HINE has been validated as a tool to predict risk for cerebral palsy (CP) and other neuromotor impairments when used longitudinally (D. M. Romeo et al., 2019). It has good interobserver reliability and

has been successfully implemented in neonatal follow up clinics to evaluate neurodevelopment (Maitre et al., 2016).

Early identification of all neurodevelopmental delays is important for a timely referral for intervention. For the purposes of the project, the neonatal follow up clinic focuses on identification of motor and cognitive delays. Motor impairments should be identified early in age, when neuroplasticity is greatest, to reduce the risk of severe motor impairment (Novak et al., 2017). The HINE has been more extensively studied in the early identification of cerebral palsy (CP) than other neurodevelopmental impairments. However, the HINE is also used to assess for other impairments in neurodevelopment such as cognitive delays (D. M. Romeo et al., 2020). A recent study linked higher global HINE scores at 2 years of age with a higher level of intelligence at 11 years of age (Uusitalo et al., 2021). Using a standardized neurological evaluation, such as the HINE, in addition to developmental screening, can provide more thorough follow up for high risk infants (Morgan et al., 2019).

The neonatal follow up clinic uses the BSID IV for general developmental evaluation, however, no standardized neurological evaluation is used. Adding the HINE to the developmental evaluation of high-risk infants may improve identification of neurodevelopmental delays. If delays are recognized at an early age, referrals for intervention can be initiated and therefore capitalize on the neuroplasticity of the immature brain. Based upon evidence reviewed, two hypotheses were made prior to implementation of the HINE in the project setting. Firstly, it was hypothesized that using the combined screenings of the HINE and the BSID IV would result in better identification of patients needing a referral for intervention for neurodevelopmental delays. Secondly, it was hypothesized that adding the HINE to the BSID IV would not result in a greater number of developmental delay diagnoses in the participants.

Review of Evidence

The literature was reviewed for trends in neonatal follow up care and developmental evaluation of preterm infants. Neurodevelopmental screening tools and examinations were the focus of the literature review for follow up care. The literature reviewed investigated the use of the Hammersmith Infant Neurological Examination (HINE) in the assessment of infants at high risk for neurodevelopmental delays and the use of the BSID II, BSID III, and BSID IV in high-risk follow up clinics. PubMed and CINAHL databases, and Cochrane Library were searched. Search terms included Hammersmith Infant Neurological Evaluation, HINE, neurodevelopmental delays, developmental delays, motor delays, prematurity, preterm infants, high risk infant follow up clinic, neonatal follow up clinic, and Bayley Scales of Infant Development. The literature review included special issue articles, systematic reviews, case control studies, longitudinal studies, cohort studies, retrospective studies, and prospective studies. Editorial or opinion articles were excluded. Articles published within the past 10 years and written in English were considered. Twenty-four articles were found that were relevant to the project topic. The themes identified from the evidence were the using the HINE for predicting neurodevelopmental outcomes of high-risk infants, comparing the HINE to other neurodevelopmental evaluation tools, and the feasibility of implementing the HINE in practice.

Predicting Neurodevelopmental Outcomes of High-Risk Infants Using the HINE

The HINE can be used to evaluate neurodevelopment in infants and children ages 2 months to 24 months (Maitre et al., 2016). High-risk infants ages 3, 6, 9, 12, and 24 months of age are ages most commonly evaluated in HRFC (Caesar et al., 2020; Maitre et al., 2016). The HINE is used as a tool in the early diagnosis of cerebral palsy (CP) (Novak et al., 2017). The global scores from the HINE are used to predict CP risk and risk for other neurodevelopmental

impairment (D. M. M. Romeo et al., 2013). A higher global score is associated with better neurodevelopmental outcomes. A score between 67-73 is considered optimal in the 3–6-month infant population. A score ≥ 73 in the 9–12-month infant population is considered optimal. (D. M. Romeo, Brogna, et al., 2016) A HINE score between 50-73 in 3–12-month-old infants may indicate unilateral CP. A HINE score less than 50 may indicate bilateral CP (Hay et al., 2018). HINE scores ≤ 40 are indicative of severe motor impairment (D. M. Romeo, Ricci, et al., 2016). The HINE is shown to be 90% accurate in aiding the diagnosis of CP in infants after 5 months of age (Novak et al., 2017). Some studies have found that the HINE may also be help in identification of other neurodevelopmental impairment such as cognitive and language delays (Maitre et al., 2016; D. M. Romeo et al., 2020).

The HINE and Other Neurodevelopmental Evaluation Tools

The assessment of the high-risk infant is multi-factorial (Voller, 2018). Neuroimaging and general movement exams, in addition to a neurological and developmental exam, are used to provide prognostic information about neurodevelopment. (Morgan et al., 2019). Neuroimaging findings can provide insight to the severity of neurodevelopmental delays (Morgan et al., 2019; D. M. Romeo et al., 2019; Setänen et al., 2016). Neuroimaging combined with results from other neurodevelopmental screening provide a more detailed neurodevelopmental prognosis (Morgan et al., 2019). General movement exams are used to assess the movement patterns of infants from birth until approximately 4 months of age. Abnormalities in movement patterns can identify risk for neurodevelopmental delays (Maitre et al., 2016). Although not all patients require neuroimaging, using a general movement exam and a neurological exam in combination still provide important prognostic neurodevelopmental information (Morgan et al., 2019). General movements exams are reported to be a better predictor of mild motor delays when compared to

the HINE, however, the HINE is shown to be an excellent predictor of severe motor delays (Caesar et al., 2020; Novak et al., 2017; D. M. M. Romeo et al., 2013).

Although evidence suggests that using multiple assessments can provide greater prognostic information, there are a limited number of studies that describe the relationship between combined assessments and later outcomes (Caesar et al., 2020; Morgan et al., 2019; Novak et al., 2017). Two studies were reviewed that directly compared BSID findings and the HINE scores in the assessment of neurodevelopmental outcomes (Kyriakidou et al., 2020; D. M. Romeo et al., 2020). The study by Romeo et al (2020) used the BSID II. Lower cognitive performance measured by the BSID II was linked to suboptimal global and subsection HINE scores. The authors concluded that the HINE scores provided information about the risk for cognitive delays. The study by Kyriakidou et al (2020) used the BSID III. In this study, delays in areas of motor and cognitive development were linked to suboptimal global and subsection HINE scores.

The Feasibility of the HINE in Practice

The HINE is consistently recognized as a good predictor of neurodevelopmental impairment in not only preterm infants, but also other high risk infant populations (D. M. M. Romeo et al., 2013; Setänen et al., 2016). Evidence supports that late preterm infants, gestational ages 34 0/7 to 36 6/7 weeks, should be monitored for neurodevelopmental delays (Chatziioannidis et al., 2018; You et al., 2019). Late preterm infants are shown to be at risk for suboptimal HINE scores in areas of posture, reflex, and global score (Chatziioannidis et al., 2018; Romeo et al., 2013). Infants with hypoxic ischemic encephalopathy (HIE) are at risk for neurodevelopmental delays (D. M. Romeo et al., 2019). Neonates with HIE, meeting certain medical criteria, are treated with therapeutic hypothermia to decrease the risk of impairment

from encephalopathy (D. M. Romeo et al., 2019). The HINE showed good results for the prediction of motor outcome in neonates treated with hypothermia (D. M. Romeo et al., 2019).

A consistent finding across the literature is the ease of use of the HINE in a clinic setting (Maitre et al., 2016). Several studies applaud the simple administration of the exam and the small amount of time needed to perform the exam (Maitre et al., 2016; Morgan et al., 2019; Romeo et al., 2019). Appointments in HRFC are often lengthy and do not allow the added time for extended evaluations. Multiple studies cite the good inter observer reliability of the HINE (Maitre et al., 2016; Morgan et al., 2019). The ease of administration, timing and reliability are all important to consider when choosing screening tools. The HINE is shown to have good predictive power at an early age for the identification of neurodevelopmental delays, particularly in the area of motor impairment (Maitre et al., 2016). Although recent evidence suggests that the HINE may be useful in predicting outcomes outside of motor impairment, more research is necessary to determine the long term prognostic value of the HINE in other areas of development (D. M. Romeo et al., 2020).

Theoretical Framework

Rogers' Diffusion of Innovations theory was applied to the DNP project. Everett Rogers described the theory in 1962 in his book *Diffusion of Innovations*. The theory is built around four main elements: Innovation, Communication Channels, Time, and Social System. (Dearing & Cox, 2018). The main elements provide the umbrella for the five stages of the innovation-decision process. The five stages are Knowledge, Persuasion, Decision, Implementation, and Confirmation. For the project, the knowledge, persuasion, and decision stages were applied. During the knowledge stage, prior conditions can influence knowledge, as can the social norms of the system. The persuasion stage involves the perceived characteristics of the innovation.

Rogers identified these characteristics as relative advantage, compatibility, complexity, trialability, and observability. The decision stage is divided into either adoption or rejection of the idea. Rogers identified categories of adopters as innovators, early adopters, early majority, late majority and laggards (Dearing & Cox, 2018).

The implementation of evidence-based practice follows the flow of the stages of the innovation-decision process. The knowledge, persuasion, and decision phases of framework were applied to the project. The HINE was the knowledge. Although the HINE was not new knowledge, it was considered new knowledge for the practice. The persuasion stage consisted of presenting the evidence to the clinic team for the use of the HINE in practice. After the persuasion stage, and the review of the evidence, the clinic team chose the implementation of the HINE as the evidenced based practice project.

Methods

An interprofessional team identified the need for better neurological assessment to recognize risk factors for neurodevelopmental delays and assess neurodevelopmental outcomes in the neonatal clinic. The HINE was chosen as the tool for neurodevelopmental assessment due to its ease of use, the minimal time it takes to perform, and the evidence for its good predication of neurodevelopmental outcomes. The project was an evidence-based practice project to determine if performing a neurodevelopmental examination, in addition to the currently used general developmental exam, would result in improved identification of neurodevelopmental delays or impairments. Permission to implement the project was obtained from the supervising physician at the neonatal follow up clinic and from the DNP council at the medical center.

The physical therapists and clinic provider were trained on proper administration of the HINE via training videos available on the HINE website. The training sessions for physical

therapists performing the HINE were taught in the early spring 2021 and the implementation of the HINE did not begin until later summer 2021. This lag caused some physical therapists to have difficulty in recalling the HINE items. Intense review of the HINE was needed prior to implementation. During this process, project implementation proved to be lengthier than expected. Data collection was difficult for the BSID only group. Due to resource deployment at the medical center, assistance from data resource personnel was not readily available. Extrapolating information from chart data was time-consuming.

Design

The project used a quantitative quasi-experimental design and convenience sampling. At the completion of the project, comparison was made between the group evaluated with the BSID IV only and group evaluated with both the BSID IV and the HINE.

Translational Framework

The Johns Hopkins Evidence Based Practice Model (JHEBP) was used for the implementation of the project. The JHEBP model gives a framework for identifying a practice question, reviewing the evidence, and evaluating the evidence for best practice (Dang et al., 2018). The model is structured into three phases. The phases are described as Practice Question, Evidence, and Translation (PET) and each is subdivided into processes (Dang et al., 2018). The practice question sought to determine if adding a neurodevelopmental screening tool to the BSID IV, a general developmental screening tool used in the practice, would improve the identification of neurodevelopmental delays. Evidence was reviewed from current literature for neurodevelopmental screening in infants at risk for neurodevelopmental delays. The Hammersmith Infant Neurological Examination (HINE) was chosen as the neurodevelopmental

assessment tool to be implemented. The HINE was then used in addition to the BSID IV for neurodevelopmental screening in the neonatal follow up clinic.

Setting

The neonatal follow up clinic is part of a large, not for profit medical center in the southern United States. The medical center has an associated children's hospital that serves as one of the region's largest referral centers for pediatric specialty care. The clinic's physical building is in an urban area off campus from the main medical center. The health care provider team at the neonatal follow up clinic consists of pediatric nurse practitioners, neonatologists, a developmental and behavioral pediatrician, and a neurologist. Other team members include a nurse coordinator, physical therapists, and speech therapists. The team collectively evaluates approximately 30 patients per week. Patients include infants discharged from a neonatal intensive care unit or infants with identified risk factors for neurodevelopmental delays. Patients range in age from 2 months to 3 years.

Sample

The sample consisted of patients attending appointments at a neonatal follow up clinic. Participants were male and female patients. Participants had a qualifying diagnosis of prematurity, neonatal abstinence syndrome, hypoxic ischemic encephalopathy, neonatal seizures, small for gestational age, or documentation of a diagnosis qualifying the infant for close observation of neurodevelopment. Participants ranged in age from 3 months to 12 months. For preterm infants, the age was calculated as a corrected gestational age. Corrected gestational age is calculated by subtracting the number of weeks born preterm from the chronological age of the patient. Male and female patients of all ethnicities and socioeconomic backgrounds ages 3 months of age to 12 months of age were included. Exclusion criteria were patients with

previously diagnosed CP and patients with previously known severe neurological impairment.

Data Collection

Post implementation, the HINE was performed for neurodevelopmental assessment of the participant. A physical therapist administered both the HINE and the BSID IV to the participant during the same visit. The HINE scores and BSID IV scores were recorded in a dedicated section of the EHR. Patient diagnoses and referrals for intervention were documented in the assessment and plan section of the patient's EHR. The data collection time was 2 months. At the conclusion of this time, the results of the participants receiving both the HINE and the BSID IV were compared to participants receiving only the BSID IV. Data for patients receiving only the BSID IV were obtained by a chart review of patients evaluated in the neonatal follow up clinic within the 2 months preceding the implementation of the HINE. Outcome data collected from both groups included diagnoses and referral for intervention. Referrals consisted of a referral to a medical specialist, an early intervention program, physical therapy, speech therapy or occupational therapy. REDcap database was used for secure storage of the collected data including age, sex, gender, diagnoses, and referrals.

Instruments

The Hammersmith Infant Neurological Evaluation was used for neurodevelopmental examination. It is validated in preterm and term infants ages 3 months to 24 months and is noted to have good interobserver reliability (Maitre et al., 2016). The HINE consists of 26 total items assessing cranial nerve function, posture, movements, tone, and reflexes. Each item on the exam is given a score of 0, 1, 2, or 3, with 3 being the optimal score for each individual item. Scoring of the HINE consists of sub section scores and a total global score (Romeo et al., 2013). The global score is calculated by adding each subsection score. The total global score is sometimes

referred to as the optimality score or global optimality score in the literature (D. M. Romeo, Ricci, et al., 2016). The global score ranges from 0 to a maximum of 78. Median and range global optimality scores are published for infants aged 3-12 months. The total score is commonly used in the literature when determining risk for neurodevelopmental delays. Individual subsection scores can be used when assessing risk for specific areas of neurological development (Maitre et al., 2016). For the purposes of this project, only the total global score was used when determining the risk for delays.

Romeo et. al. (2013) published a median score and a range of HINE global scores based upon a longitudinal cohort analysis of the HINE scores from infants discharged from a NICU. These range of scores were then grouped together based upon age and neurological outcomes. Romeo et. al. (2016) further evaluated global scores and subsection scores of term and preterm infants ages 3 months to 12 months to determine if gestational age affected the HINE score. Participants in this study were grouped into categories based upon gestational age at birth. Categories were defined as term ≥ 37 weeks' gestation, late preterm between 33-36 weeks' gestation, or very preterm ≤ 32 weeks' gestation. The researchers in this study published a median and a range of global scores for each category of infants (D. M. Romeo, Brogna, et al., 2016). The global score ranges and medians associated with normal neurological outcomes were similar to the previously published study by Romeo et. al. (2013). Table 1 displays the reference median and range global scores.

Table 1*Median and Range HINE Global Scores*

Age	3 months	6 months	9 months	12 months
Term infant	65.5 (62-69)	69 (64-74)	72.5 (65-78)	74 (65-78)
Late preterm	62 (57-69)	66 (60-72)	71 (63-75)	73 (64-77)
Very preterm	62 (51-67)	66 (52-71)	70 (57-76)	72 (60-77)

Note. Adapted from “Early psychomotor development of low-risk preterm infants: influence of gestational age and gender,” by Domenico M. Romeo, Claudia Brogna, Francesca Sini, Mario G. Romeo, Francesco Cota, and Daniela Ricci, 2016, *European Journal of Paediatric Neurology* 20(4), p. 521 (<https://doi.org/10.1016/j.ejpn.2016.04.011>).

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Based upon the Romeo et. al. (2016) study results, the researchers concluded that the data obtained from the study could be used as reference data for the assessment of developmental outcomes in preterm and term infants at risk for delays (D. M. Romeo, Brogna, et al., 2016). The published median and range of scores for term, very preterm, and late preterm infants with normal neurological outcomes were used for interpretation of results (D. M. Romeo, Brogna, et al., 2016). For the interpretation of project results, participants with a median score or above were regarded within range. The participants with scores within range were considered to have a lower risk for neurodevelopmental delays and routine follow up was recommended. Participants with scores at the lower end of the range were reported as low range. Participants with scores at the lower end range were considered at risk for delays and warranted closer follow up. Participants with scores below the range were reported as below range and were considered at

highest risk for neurodevelopmental delays and close follow up and multidisciplinary care was warranted.

The HINE has individual scoring proformas that are printable and used to manually record the subsection and total scores for each participant. The HINE also includes two sections that are not scorable. These sections are behavior observations and milestone observations. Examiners can make observation notes in these sections during the exam, but the observations are not scorable and are not used in calculating the subsection score or global score. Asymmetry of movement scores for each subsection have been developed to help with the prediction of hemiplegic CP. Asymmetry scores range from 0-5. Asymmetry scores greater than 5 are associated with hemiplegic CP (Hay et al., 2018). The project did not include behavior and milestone sections of the HINE or asymmetry scores.

The BSID IV was used as the evaluation tool for general developmental assessment. It can be used to assess the development of infants and children from 16 days of age to 44 months of age. The BSID IV proposes to correct some of the overestimation of motor delays associated with the BSID III (Anderson & Burnett, 2017). The BSID IV consists of motor, cognitive, language, and social/behavioral domains. For the categories of cognitive skills, gross motor skills, fine motor skills, expressive language, and receptive language a raw score is calculated based upon developmental tasks that are presented in the evaluation. Each task completed within the category is assigned a point value to determine the raw score of each category. The raw score for each category equates to an age equivalent score. The age equivalent score gives the age level in months at which the participant performs the developmental tasks. For this project, the age equivalents from the cognitive, fine motor, and gross motor categories were used to determine

developmental delay. The BSID IV has individual printable scoring sheets that were used to manually record the scores for each participant. The scoring sheet was scanned in to the EHR.

Data Analysis

Descriptive statistics were used to describe the sample population. Fisher's exact test to compare categorical data was used to evaluate the association between the number of participants qualifying for referrals between the BSID IV only group and BSID IV and HINE group. A Chi squared test to compare categorical variables was used to evaluate the association between the participants in the BSID IV only group with or without the diagnosis of developmental delays and the BSID IV and HINE group with or without the diagnosis of developmental delays. In the post-implementation group that received both the BSID IV and the HINE, a Fisher's exact test was used to determine the association between the BSID IV results and the HINE results.

Results

Sample Demographics

A total of 105 participants were included in the project. 45 participants were female, and 60 participants were male. 31 participants received the BSID IV and the HINE for developmental evaluation. 74 participants received only the BSID IV for developmental evaluation. The age of preterm participants was adjusted to account for prematurity. Ages of preterm participants are reported as the corrected gestational age in the project data. The mean gestational age at birth was 30.88 weeks. The mean age in months at the time of the developmental evaluation was 6.23 months. Table 2 displays the sex and gestational age demographics of the participants. In addition to a diagnosis of preterm or term, some participants

had a secondary diagnosis qualifying them as high-risk for developmental delays. Table 3 shows the number of secondary diagnoses.

Table 2

Sex and Gestational Age Demographics

		Gestational Age at Birth		Total
		<37 weeks gestation	>37 weeks gestation	
Sex	Female	41	4	45
	Male	50	10	60
Total		91	14	105

Table 3

Secondary Diagnoses of Participants

Diagnosis with risk for delay	<i>n</i>
Encephalopathy	6
Hydrocephalus	2
Hypertonia	4
Hypotonia	5
In utero drug exposure	12
Microcephaly	1
Seizures	3
Trisomy 21	1
Vater syndrome	1
Ventriculomegaly	2

Participants qualifying for referral for intervention

The number of participants qualifying for a referral for identified delays were compared between the two participant groups. Table 4 displays the number of participants qualifying for a referral for each group.

Table 4*Participants Qualifying for Referral per Evaluation Tool*

		Referrals				
			Qualified-referred prior to evaluation	Did not qualify	Qualified	Total
Evaluation tool	BSID IV	<i>n</i>	4	60	10	74
			5.4%	81.1%	13.5%	
	BSID IV+HINE	<i>n</i>	3	24	4	31
			9.7%	77.4%	12.9%	

The results of the Fisher's exact test did not show evidence of a significant relationship between the developmental testing used and the number of participants qualifying for referrals. Fisher's exact = .847, $N = 105$, two-sided $p = .722$. Adding the HINE did not change the number of participants qualifying for referrals made for intervention for delays.

Developmental Delay and Evaluation Tool used

The number of participants in the BSID IV only group and the BSID IV and HINE group with the diagnosis of developmental delays based upon evaluation tool is displayed in Table 5.

Table 5*Delay Diagnosis per Evaluation Tool*

		Delay Diagnosis			
			Developmental delay	No delay	Total
Evaluation tool	BSID IV	<i>n</i>	17	57	74
		%	23.0%	77.0%	
	BSID IV+HINE	<i>n</i>	4	27	31
		%	12.9%	87.1%	

The Chi square test of independence did not show evidence of a significant relationship between the BSID IV only group and the BSID IV HINE group and the outcome of

developmental delays $\chi^2(1, N = 105) = 1.385, p = .239$. Adding the HINE did not identify more delays than the BSID IV used alone.

Relationship Between BSID IV and HINE Results in Post-implementation Group

The Fisher's exact test showed evidence of a significant relationship between the BSID developmental outcome results and the results of the HINE. Fisher's exact value = 12.899, $N = 31$, two-sided $p = <.001$. The BSID IV and the HINE showed similar results when identifying developmental delays in the group receiving both the BSID IV and the HINE. Six participants in this group had a HINE score within the low range and did not show developmental delays on the BSID IV. Two participants in this group had below range HINE scores and did not show delays on the BSID IV.

Discussion

The purpose of implementing the HINE in developmental follow up of high-risk infants was to identify neurodevelopmental delays as early as possible. Early identification of neurodevelopmental delays is important to improve neurodevelopmental outcomes in the population of high risk infants (Novak et al., 2017). The HINE is a quick neurological examination that is used in patient populations with high risk for neurodevelopmental delays (Maitre et al., 2016). Incorporating the HINE into the developmental evaluation with the BSID IV did not result in more delay diagnoses and did not identify more participants qualifying for a referral for intervention compared to using the BSID IV alone. However, the HINE was able to identify patients at risk for neurodevelopmental delays not captured by the BSID IV alone.

Referral for intervention

It was hypothesized that adding the HINE would result in more participants qualifying for referrals for intervention. Because the HINE is a neurological exam, it was anticipated that

adding the HINE would identify more neurological impairments that would put patients at risk for motor delays. The HINE is shown to have a high predictive power for the prediction of CP after five months of age therefore more referrals for motor impairments were expected (D. M. Romeo et al., 2020). Statistical analysis results did not show a significant association in the qualification for referral between the BSID IV only group and the group receiving the BSID IV and the HINE. The link between the HINE score and neurodevelopmental outcomes, other than motor delays, is important to consider when discussing referrals for intervention. The participant sample consisted of patients 1 year of age or less. Outcomes such as cognitive delays or speech delays may not be as apparent in the younger ages of the sample participants. According to Uusitolo, et al (2021), a higher global HINE score at 2 years of age is associated with higher intelligence, better verbal skills, and better reasoning and processing skills. It is possible that if the participant sample included patients up to age 2 years, the referrals may have been more closely associated with the evaluation tool used.

While the project results did now show the HINE resulted in more referrals, the HINE still identified participants needing further intervention. Seven of the study participants in the BSID IV and HINE group were referred for intervention prior to receiving the evaluation in the neonatal follow up clinic. For the data analysis, these participants were grouped in a separate category and were not included in the qualification for new referrals category. Of those seven participants referred prior to the evaluation, three participants were given a diagnosis of developmental delay and would have qualified for a referral if not previously referred. Three participants in the BSID IV only group were given a diagnosis of developmental delay per the evaluation. Despite being previously referred for intervention for possible delays, one participant in the BSID IV only group did not have a delay diagnosed per the evaluation. Both the BSID IV

only and BSID IV and HINE were able to identify the delays in six participants that would have resulted in a referral for intervention. Six patients receiving a referral was clinically significant for early identification of impairments. The early identification allowed for a referral to improve clinical outcomes.

Identification of neurodevelopmental delay

The BSID IV and HINE used together did not show a significant difference in the diagnosis of developmental delays. It was hypothesized that adding the HINE to the BSID IV for neurodevelopmental screening would not result in a greater number of neurodevelopmental delays. The BSID, regardless of the edition used, remains the standard of care for developmental evaluation and delay identification in neonatal follow up (Anderson & Burnett, 2017). One study evaluating the BSID III determined that subsections of the BSID III were better at predicting typical development in the 3–6-month ages than predicting atypical development (Lobo et al., 2014). Because the project sample population consisted of these younger 3–6-month ages, it is possible that the BSID IV scores reflected more typical development versus atypical development. The BSID IV was used in the project instead of the BSID III. However, there is evidence that the BSID IV reports similar scores compared to the BSID III (Aylward, G.P. & Zhu, J., 2019). The BSID gives an overall picture of developmental milestone progress with age equivalents for the raw scores of each subsection of the exam. The HINE provides a neurological examination and does not give an age equivalent for specific milestones. These differences could explain why more delays were not diagnosed when adding the HINE. Although adding the HINE did not result in a greater number of diagnoses of neurodevelopmental delays in the project sample, identification of neurological abnormalities is important in overall neurodevelopmental prognosis (Maitre et al., 2016).

Identification of risk for neurodevelopmental delay

Statistical analysis showed a significant relationship between the results of the BSID IV and the results of the HINE in the group receiving both screenings. All participants receiving both screenings with a developmental delay per the BSID IV, also had a below range HINE score. While the results of the BSID IV and the results of the HINE were significantly associated, there were some notable differences. In 2 participants, the BSID IV alone did not identify a delay, however the HINE score was below range. The below range HINE score, despite the BSID IV not showing delays in milestones, prompted closer follow up and referral for intervention for these participants. In 6 participants with no delays identified by BSID IV results, the HINE results were in the low range. The lower range HINE score could be interpreted as a risk factor for future neurodevelopmental impairment and warrant closer monitoring (D. M. Romeo et al., 2020). A potential explanation for these differences in results is the HINE identifies neurological abnormalities in tone, reflexes, and movement patterns. Neurological abnormalities identified by the HINE may not result in immediately identifiable developmental delays reflected on the BSID IV general developmental assessment. The HINE is excellent at prediction of severe motor delays at an early age, but mild or moderate motor delays may not be identified as early as severe delays (D. M. Romeo et al., 2020). Evidence has shown that there is a closer correlation between the HINE global scores in the 3-12 month ages and overall neurodevelopmental outcomes at 2 years of age (D. M. Romeo et al., 2020). Therefore, the age of the participants should be considered in interpreting these results. The participant sample mean age was 6.23 months. At this young age, there are a smaller number of motor and cognitive developmental milestones to be achieved compared to older infants and toddlers. The HINE is designed to be repeated at intervals of time and tracking global scores over time may

help to further identify delays in neurodevelopment (Maitre et al., 2016). Repetitive use of the HINE may provide a better insight into neurodevelopmental progress as the brain matures (Maitre et al., 2016).

Application of JHEBP Model

The practice question aimed to determine the best tools for neurodevelopmental evaluation. The JHEBPM provided the translational framework for identifying the practice question, reviewing evidence, and determining the best evidence for practice. The clinical team members at the neonatal follow up clinic wanted to improve neurodevelopmental evaluation the patients referred to the clinic. After review of the literature, the HINE was chosen as a screening tool to use in addition to the BSID IV for neurodevelopmental evaluation. Based upon the results of the project, our clinic team chose to use the HINE in neurodevelopmental evaluation. The evidence showed that the HINE is a clinically useful tool for neurodevelopmental evaluation in neonatal follow up. It should not be used alone, but in addition to other neurodevelopmental evaluation tools for the diagnosis of neurodevelopmental delays or abnormalities (Morgan et al., 2019). The HINE will continue to be used in the neonatal follow up clinic to track neurodevelopmental progress of patients. The goal of neonatal follow up is to recognize early signs of neurodevelopmental developmental delays in hopes of improving outcomes.

Application of Rogers' Diffusion of Innovations theory

Rogers' Diffusion of Innovations theory guided the innovation-decision process for the implementation and eventually the adoption of the HINE into practice. The theory's main elements of innovation, communication channels, time, and social system were applied to the project implementation process. The collective knowledge of the team was important in determining the innovation. Communication within our team was not difficult due to the small

size of our team. Team members have long-standing professional relationships with each other. These advantages streamlined communication about the project. The social system within our clinic and between our clinic and system administrators is conducive to the implementation of new ideas.

The knowledge, persuasion, and decision phases of framework were applied to the project. Persuasion, knowledge, and decision phases of the diffusion of innovation continuum were applied to the project implementation. Advantages, compatibility and trialability of the HINE were all considered during the persuasion stage. Prior to choosing the HINE, team members were already aware of the HINE and its potential benefit in neurodevelopmental evaluation. Our team consisted of early adopters of the innovation. Because of the early adopters, there was not much persuasion needed in choosing the HINE. Our team needed an evaluation that was quick and effective. The HINE had the most evidence for compatibility for the patient population in the clinic, therefore, the decision to implement the HINE was an easy choice.

Limitations

A significant limitation to the project was the total sample size and the sample size of each group. The overall sample size was small and there were more participants in the BSID IV only group than the BSID IV and HINE group. The time frame for the post implementation data collection was set at 1-2 months and occurred during July 2021 and August 2021. A chart review was performed for data collection for the BSID IV only group. Data from patients evaluated during May 2021 and June 2021 was used. The number of patients seen in the clinic each month depends on multiple factors. Some factors, such as operational clinic days, are controllable. Other factors such a no-show rate and reschedule rate, are not controllable. The months of July

and August incorporated vacations that caused less operational clinic days and the rate of no-shows or rescheduled visits was higher in the months of July and August versus May and June. A larger sample size would likely allow for better translation of evidence into practice.

Recommendations for Future Study

The HINE is designed for repeated use for identification of neurological abnormalities and early prediction of CP (Novak et al., 2017). Going forward, studies in the neonatal follow up clinic should include following HINE scores over time. Longitudinal studies could help explore the relationship between the HINE scores and longer-term neurodevelopmental outcomes. Evidence in the literature suggests that the HINE can predict more than motor delays and may be useful in the prediction of cognitive outcomes (D. M. Romeo et al., 2020). Longitudinal studies exploring the relationship between the BSID IV results, and the HINE results could provide more information about the benefit of using more than one developmental screening tool to evaluate neurodevelopment.

For future projects, timing for all stages of the project should be carefully considered. If training is necessary, it would be more practical to have the training closer to the time of implementation. The timing for data collection may need to be expanded for future projects to produce a larger sample size and possibly more applicable results. Due to the timeline for completion of the DNP project, it was not possible to extend the time frame for data collection.

Relevance and Recommendations for Clinical Practice

The HINE is a valid and useful tool for neurodevelopmental evaluation (Maitre et al., 2016). It is readily available and easy to implement (Maitre et al., 2016). While results from adding the HINE project did not show statistically significant evidence for improving referrals for neurodevelopmental delays, the HINE was clinically useful in the identification of the risk for

delays. When compared to the BSID IV alone, the HINE was able to identify clinical neurodevelopmental abnormalities in some participants. Because the HINE was clinically useful in evaluation risk for delays, our team will continue to use the HINE in practice. Repeated use of the HINE is reported to be most beneficial in the identification of delays (Maitre et al., 2016), therefore when the HINE is used in our practice, it will be repeated at subsequent visits. The repeated results will be compared over time to assist in the recognition of neurodevelopmental impairments.

Other HRFC may benefit from use the HINE. It is easy to implement, and the materials and training are free of charge. Given the evidence in the literature for the HINE as a good predictor neurodevelopmental outcome, using the HINE in evaluation of high-risk infants could be helpful in identification of delays. Collective use of the HINE in other HRFC would give more data to track neurodevelopmental outcomes of high-risk infants.

Conclusion

Patients in a neonatal follow up clinic are at high-risk for neurodevelopmental delays (Voller, 2018). The HINE is a neurological evaluation used to identify neurodevelopmental delays (Novak et al., 2017). The BSID is the predominantly used developmental evaluation in neonatal follow up (Anderson & Burnett, 2017). Evidence shows that using more than one screening tool for neurodevelopment can give a better assessment of neurodevelopmental outcomes (Morgan et al., 2019). Adding the HINE as another tool for evaluation can provide important information about neurodevelopmental progress. As evidenced in the relationship between the BSID results and HINE results in the project, adding the HINE identified patients at risk for delays. Once the risk was identified, this allowed for closer monitoring of development.

The continued use of the HINE in the neonatal follow up clinic will be used to evaluate patient outcomes and improve identification of delays or impairments.

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