Amplitude-Integrated Electroencephalography Interpretation During Therapeutic Hypothermia: An Educational Program and Novel Teaching Tool

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The purpose of this article is to provide nurses with evidence-based rationale for the use of aEEG interpretation during TH, including all of the tools and products for the staff education.

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Abstract

Therapeutic hypothermia (TH) is now considered a standard in tertiary NICUs. Amplitude-integrated electroencephalography (aEEG) is an important adjunct to this therapy and is gaining acceptance for use on the neonatal population. It can be easily incorporated into practice with appropriate education and training. Current publications are lacking regarding nursing care of neonatal patients undergoing TH with the use of aEEG. This article presents a broad educational program as well as novel teaching tool for neonatal nurses caring for this population.

Keywords: amplitude-integrated electroencephalography (aEEG); hypoxic-ischemic encephalopathy (HIE); therapeutic hypothermia; nursing; education

Each year in the United States, there are an estimated four million births.[1] Of those births, there are one to four infants per 1,000 who will experience an insult at birth that results in hypoxic-ischemic encephalopathy (HIE).[2] Globally, up to two-thirds of newborns who develop HIE die, and approximately one-fourth of those who survive will have severe neurodevelopmental sequelae.[3] Brain injury caused by HIE is the top contributing cause of neurodevelopmental disabilities,[4] the most common being cerebral palsy (CP).

Several tools are required in order for the provider and bedside nurse to accurately identify and quickly treat newborns affected by HIE. One of those tools is the amplitude-integrated electroencephalogram (aEEG). The aEEG is an important adjunct in the prediction of long-term neurologic outcomes for infants with HIE.[5–7] The use of aEEG allows the bedside provider to identify seizure activity that is not always recognized by visual assessment. The aEEG use and interpretation can be incorporated into the practice of the bedside provider with an appropriate education program and adequate resources. With appropriate training, the provider may be able to identify and treat seizure activity that could be overlooked otherwise and may minimize the neurologic damage sustained during HIE.[8,9]

Pathophysiology of Brain Injury

HIE is caused by either placental, fetal, or maternal insult or injury that results in neonatal brain hypoxia. The brain injury that occurs following a hypoxic-ischemic insult

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occurs in two phases. In the first phase, the neonatal brain responds by converting to anaerobic metabolism, leading to depletion of adenosine triphosphate, increased lactic acid production, and a disturbance in normal metabolic activity. This response disrupts intercellular pumps in the brain and causes a buildup of sodium, calcium, and water, which produces accumulation of fatty acids and oxygen-free radicals. These events, together, cause cell apoptosis. Preceding the initial injury to the neonatal brain, a second phase of injury will ensue if intervention is not initiated.[4,10,11]

The second phase of HIE, which involves several processes and is not well understood, includes accumulation of excitatory neurotransmitters and cell apoptosis. Once the second phase begins, any brain injury that occurs in this phase is irreversible.[11]

Seizures occur in this population as a result of the brain injury sustained during a hypoxic event. Seizures are one of the most common signs of neurologic dysfunction and can occur very early, even before the second phase, postnatally. If left unnoticed or untreated, frequent seizures can further increase the amount of damage to the neonatal brain. The diagnosis of neonatal seizures can be challenging because as many as 80 percent of infants have clinical signs that are subtle or absent. This can be especially difficult in seizures that are a result of brain injury from HIE because many of these infants require intubation and paralytics, further masking the clinical signs of seizure activity.[12,13]

Treatment for HIE must occur rapidly to avoid further damage. Therapeutic hypothermia (TH) for treatment of HIE has become the gold standard and has demonstrated positive outcomes for mild to moderate cases of HIE.[4,11,14] Currently, there are two forms of cooling: selective head cooling[15] and total body cooling.[16] Both methods have proven effective with minimal side effects. The benefits of this intervention outweigh the side effects and, therefore, this intervention has been implemented in many centers after proper training has occurred.[2,17,18] Specific protocols have been developed for each method of cooling, which have been easily translated to practice in both community and academic centers. Infants who meet HIE criteria, as defined in each protocol, are cooled to 33.5°–35°C within six hours after birth and are maintained at that temperature for 72 hours, following a slow rewarming process.[15,16,19]

Infants are monitored closely by various methods, including aEEG. The aEEG is a cerebral function monitor that time-compresses, rectifies, and filters the conventional electroencephalogram (cEEG), which can be visualized and interpreted by the bedside provider. The aEEG is easily set up at the bedside and can be applied by the bedside nurse.[8,20] Although cEEG is considered the gold standard for the accurate detection of seizure activity in the neonate, it is tedious to apply and requires evaluation by a neurologist or neurophysicist specially trained in reading the neonatal cEEG.

In this article, the importance of aEEG for bedside seizure identification in infants will be established, the lack of existing publications regarding nursing care for these infants identified, the mechanics of how aEEG is used described, and models of teaching about aEEG and cooling therapy to other clinical groups reviewed. A broad educational program for neonatal nurses, including innovative teaching tools, implementation, and systems change, will be presented.

SIGNIFICANCE

The use of the aEEG monitor by bedside providers for early identification and detection of seizure activity is an important aspect in the management of infants with HIE undergoing TH. Because TH is offered in institutions of different levels, aEEG monitoring by bedside providers is especially beneficial within institutions, where neurologists or neurophysicists are not readily available to assess the infant and evaluate for seizure activity.[18,21]

When abnormal background and seizure activity is identified, monitored, and treated effectively and efficiently, the associated negative outcomes are significantly reduced.[5,6] Because of increased risk of seizure activity associated with HIE, it may be advantageous for the bedside nurse to have the ability to assess with aEEG. The bedside nurse provides ongoing care and assessment of these infants on a continual basis, making him or her critical for the identification of changes in aEEG. It is imperative that nurses are educated regarding aEEG use and interpretation to correctly identify the subtle changes that can occur on the aEEG and report to the provider quickly and efficiently.

It has been demonstrated that nurses who are provided with critical thinking education and subsequent protocols are the most effective caregivers for the neonatal population.[22–24] Although there are many published articles related to the use of aEEG for seizure identification in infants treated with TH, there are no published articles in which innovative tools for teaching interpretation of aEEG are presented.

EVIDENCE APPRAISAL

The focus of the review and appraisal of the literature is on the aEEG, including its benefits for infants with HIE who receive TH, interpretation, and training with the focus on neonatal data. This evidence appraisal was the basis for the approach and content of the development of the educational program. The literature search was performed between January 2013 and June 2014. Many searches were done using PubMed, Cochrane Database of Systematic Reviews, Academic Search Complete (EBSCO), and Cumulative Index for Nursing and Allied Health Literature databases. The search terms included neonates/newborns/infants, HIE, TH, aEEG, interpretation, nurses, and training. Included in this evidence appraisal are one meta-analysis, five randomized controlled trials, one nonrandomized controlled trial, three systematic reviews, and three retrospective chart reviews.

BENEFITS OF aEEG DURING THERAPEUTIC HYPOTHERMIA

An aEEG, when applied prior to initiation of TH, provides an assessment of baseline brain background pattern after suspected HIE. Once TH is initiated, the effectiveness of the cooling treatment can be continuously evaluated with aEEG. Once aEEG is applied, it provides valuable information on brain function and neonatal sleep–wake cycles.[5,25–27] The review of the literature performed yielded three articles documenting the ability of the aEEG to predict neurologic outcomes in neonates treated with TH for HIE: one meta-analysis that included eight articles and two retrospective chart audits.

Abnormalities in the aEEG at initiation of TH are not predictive of negative neurologic outcomes. In neonates with mild to moderate HIE who are treated with TH within the therapeutic window, these abnormalities in aEEG tracings have been shown to dramatically decrease and cease in many cases consistent with improved neurologic function.[5,7,25] However, if abnormalities in the aEEG are seen continuously throughout cooling and rewarming, there is a 100 percent positive predictive value of severe neurologic disabilities.[6,28–30]

Spitzmiller and colleagues performed a meta-analysis to evaluate the accuracy of aEEG in predicting developmental outcomes for infants with HIE.[6] Eight articles were included from a literature search from 1966 to 2005, with the primary outcomes of interest being abnormal neurologic exam performed by a pediatric neurologist, HIE as defined by the Sarnat scoring system[31] CP, or a documented developmental quotient <85 based on Griffiths[32] Developmental Scale. There were 543 infants with gestational ages ≥36 weeks. The authors found that severe aEEG tracings are accurate in predicting poor outcomes with 91 percent pooled sensitivity and 0.09 pooled negative likelihood ratio. A weakness of this study is that the effect size of the included articles is relatively small; however, the authors believed that they had enough information to accurately contribute to the analysis. Also, not all infants in the articles included in this analysis were cooled. Strengths of this study include blinded tracing interpreters, the window at which aEEG is applied was similar in all studies, and aEEG interpretation was done by one criteria set.

Hallberg and colleagues conducted a retrospective study to evaluate aEEG data during TH and their ability to predict long-term outcomes at one year of life.[25] From December 1, 2006, to December 31, 2007, 23 infants qualified for cooling based on the Swedish national guidelines for induced hypothermia in newborn infants ≥36 gestational weeks following perinatal asphyxia. The aEEG data were assessed by blinded independent researchers at 6, 12, 24, 36, 48, and 72 hours after birth using Hellström-Westas criteria.[33] These infants were given neurologic exams at 2, 6, and 12 months of age. They also received a neuromotor assessment at four months of age with the Alberta Infant Motor Scale (AIMS). This study revealed that infants treated with TH for moderate to severe birth asphyxia with normal aEEG data after 24 hours of life had normal outcomes at one year of life. Limitations to this study are the small sample size and lack of long-term follow-up evaluation beyond one year of life. Strengths include blinded researchers, evaluation of aEEG at specific times, and all infants were followed up with at one year of life.

Massaro and colleagues retrospectively reported on aEEG data from infants with HIE treated with TH.[29] Seventy-five infants were included in this study from May 2006 to May 2009. Abnormal outcomes were defined as death or clinical/radiologic evidence of brain injury before discharge from the hospital. Data from the aEEG were reviewed by an experienced reader using Hellström-Westas criteria.[33] Interrater reliability was measured and presented. This review demonstrated that absence of aEEG recovery and sleep–wake cycling is predictive of negative outcomes in HIE infants treated with TH. Limitations to this study are the small sample size and the inability to assess aEEG before 12 hours of life and lack of long-term follow-up.

The aEEG has been documented to accurately predict negative outcomes as well as cEEG in several randomized controlled trials.[34,35] This gives the provider valuable information throughout cooling that allows them to more accurately inform parents and caregivers of outcomes for their newborn. It also allows for time to discuss care options and make decisions regarding palliative care if appropriate.

AMPLITUDE-INTEGRATED ELECTROENCEPHALOGRAPHY INTERPRETATION DURING THERAPEUTIC HYPOTHERMIA

The TH affects the newborn's normal body processes in several ways. As a result, the aEEG is altered during cooling, and interpretation evolution is essential in determining patient outcomes. Once a baseline is established, cooling should commence immediately.[5,6,25,28,29] There are three main aspects of the aEEG that can be evaluated prior to and during TH and rewarming: pattern and voltage deviations, sleep–wake cycles, and seizure activity.

There are two classification systems for interpretation of the aEEG during cooling in term infants. Hellström-Westas and colleagues established a classification system based on pattern recognition for HIE infants defined as continuous normal voltage (CNV), discontinuous (DC), burst suppression (BS), low voltage (LV), and flat (FT).[33] al Naqeeb and colleagues developed a voltage classification system defined as normal amplitude, moderate abnormal amplitude, and suppressed or severely abnormal amplitude.[20] These two classification systems are summarized in Table 1. Both of these classification systems have been used by providers in randomized controlled studies and have demonstrated accurate interpretation of the aEEG during TH.[7,18,21] These classification systems are used to identify abnormal patterns that can aid in the determination of outcomes for infants with HIE.

TABLE 1 ■ Summary of aEEG Classification Systems

	Hellström-Westas et al[33]	al Naqeeb et al[20]	
Normal tracing	Continuous normal voltage (CNV): Continuous activity Lower margin 5–10 μV Upper margin 10–50μV	Normal amplitude: Upper margin >10 μV Lower margin >5 μV	Normal tracing
Normal tracing	Discontinuous (DC): Discontinuous background Lower margin <5 μV Upper margin >10 μV	Moderately abnormal amplitude: Upper margin >10 μV Lower margin ≤5 μV	Abnormal tracing
Abnormal tracing	Burst suppression (BS): Discontinuous background Lower margin 0–2 μV Bursts >25 μV	Suppressed amplitude: With burst suppression Upper margin <10 μV Lower margin <5 μV	Abnormal tracing
Abnormal tracing	Low voltage (LV): Continuous background Lower margin ≤5 μV		
Abnormal tracing	Flat (FT): Inactive Lower margin <5 μV		

Abbreviation: aEEG = amplitude-integrated electroencephalography.

Another aspect of the aEEG is the ability to evaluate sleep–wake cycling (SWC). A SWC is present in all normal term infants and can be used to evaluate and predict prognosis in infants undergoing TH. A SWC involves many areas of the brain and reflects integrity, maturity, and organization of the entire brain.[27] A SWC is demonstrated by continuous activity on the aEEG with regularly cycling patterns. These cycling patterns consist of intervals of continuous activity during awake and active sleep periods and periods of slightly lower voltage during quiet sleep. For a term infant, the broadest bandwidth should be a minimum of 6–8 μV and maximum of 15–20 μV, and the narrowest bandwidth should be a minimum of 6–8 μV and maximum of 9–15 μV.[7] Massaro and colleagues did a retrospective chart audit of 75 newborns treated with TH.[29] Of the infants with favorable outcomes, SWC were present on Day of Life (DOL) 1 in 5 percent and by DOL 4 in 58 percent. Conversely, no infants with negative outcomes had SWC.[29] Takenouchi and colleagues did a retrospective chart audit of 31 infants treated with TH.[27] In the 22 infants with normal outcomes, 14 had return of SWC by 120 hours of life.[27] Return of an abnormal aEEG to a CNV pattern with recognizable SWC has been shown to positively predict normal outcomes for infants with moderate to severe HIE.[5,27,29]

Seizure activity can also be identified using the aEEG and follows the cEEG pattern recognition definitions. The newer aEEG machines present both the aEEG background pattern along with the raw EEG pattern. Small changes in the aEEG can be compared with the raw EEG in real time, can represent seizure activity, and should be evaluated immediately. This quick evaluation ability and the presentation of both backgrounds simultaneously increase the likelihood that brief seizure activity will be identified.[34] In a study by Bourez-Swart and colleagues, 12 term infants were monitored with both the aEEG and cEEG during TH and rewarming.[35] The aEEG was interpreted by two experienced neonatologists, and the cEEG was interpreted by two neurophysiologists and one technician; both were blinded to the results. The observers were able to identify seizure patterns with 100 percent sensitivity using the multichannel aEEG. The aEEG correlates with a very high positive predictive value with the cEEG for identification of seizure activity.[35] Not all seizure activity can be recognized on the aEEG, especially brief focal seizures that do not occur in the sections of the brain that are picked up by the two-channel aEEG. This is why aEEG is an important adjunct, and cEEG should still be used and evaluated by a neurologist at some point during the cooling process.

AMPLITUDE-INTEGRATED ELECTROENCEPHALOGRAPHY TRAINING

Only five articles from the literature search have been published in which the training that providers undergo prior to initiation of an aEEG monitor during TH is described. Whitelaw and White outlined a dedicated one-day program for neonatologists that requires preparation prior to the class. The class is only offered twice a year in Europe.[9] The authors discussed the importance of nurse recognition of abnormal patterns on the aEEG and prompt reporting to providers.

In three studies, it was mentioned that it was possible for providers with minimal training in aEEG to accurately identify seizure activity and recognize specific patterns with high interobserver reliability when compared with experts, demonstrated by k statistic values of >0.65.[8,20,34]

Griesmaier and colleagues conducted a feasibility study to assess several features related to the implementation of aEEG monitoring in preterm infants over a two-year period.[36] One of those features was the ability of neonatal nurses and physicians to accurately interpret aEEG recordings in preterm infants. The physicians received three-hour-long aEEG training sessions each year that included physiology, pattern recognition, and technical aspects. The nurses received education on application of electrodes, monitor setup, and to watch for sudden changes in aEEG pattern. After two years of using aEEG in their unit, approximately 75 percent of physicians and 50 percent of nurses were able to identify aEEG patterns and seizure activity. Limitations to this study include a small number of surveys received, focus on use of aEEG on the preterm population, and that this study was conducted in Europe, where regulatory systems differ and the aEEG machine is able to provide different options regarding seizure alerts. However, the data presented demonstrate that nurses were able to identify seizure activity and aEEG patterns half the time. With regular education and evaluation, successful implementation and use of aEEG in the NICU is possible. No articles have been written to date regarding neonatal nurse education and use of aEEG at the bedside.

From the evidence presented, the information obtained from the aEEG is an important aspect of the management of infants affected by HIE. The aEEG yields details related to outcomes and can signify seizure activity that might be missed otherwise. The bedside nurse is an integral part of the treatment team, and his or her ability to identify changes in the aEEG is essential. With that being said, bedside nurses have to use their critical thinking skills as well as complete several tasks throughout their shift. The development of this program and innovative teaching tool assists the bedside nurse in gaining new knowledge and the ability to apply that knowledge. The innovative teaching tool acts as a job aid that allows for identifying changes in the aEEG and acts as a sort of checklist to facilitate identification of changes in the aEEG and decrease the amount of time spent at the monitor.

aEEG Education Program Development

A multifaceted, enduring educational program was developed with a nursing care plan to assist the cooling team nurses in identifying changes in the aEEG during TH and rewarming. This included education for, and implementation of, an innovative measuring caliper to make the interpretation easier. This program content included background pathophysiology of HIE and instruction related to setup of an aEEG monitor, placement of electrodes, evaluation of voltage and pattern recognition, seizure patterns, and appropriate reporting (Tables 1–4).

TABLE 2 ■ Course Objectives for aEEG Educational Program Components

Educational Component	Course Objectives
aEEG history, development, and basic strip evaluation	Present the history on aEEG development and use
	Define an aEEG
	Discuss interpretation criteria
	State current outcomes
	Explain what is in the literature and future research
In-depth aEEG voltage and pattern recognition	Answer any questions regarding aEEG education thus far
	Identify important markers on aEEG monitor
	Define voltage criteria and patterns
	Define SWC and seizures
	Practice
Simulation lab	Review of policy and procedure
	Review of educational material to date
	Practice use of equipment, procedures, and documentation
	Simulation based on case study

Abbreviations: aEEG = amplitude-integrated electroencephalography; SWC = sleep–wake cycling.

This project was designed for use at a community hospital Level III NICU in the Pacific Northwest, with the intention that the program can be easily assimilated and applicable to other units. Currently, this is a 20-bed Level III NICU with approximately 325 admissions per year, of which approximately six cases per year involve infants with HIE. The unit consists of 63 neonatal nurses, with most of these nurses having no experience with TH or aEEG use.

Neonatal Nursing Education: Therapeutic Hypothermia and aEEG

The aEEG education program was provided to all full-time nursing staff and medical staff as a component of the TH education program developed for this unit and represented three hours of didactic material and two hours of the simulation lab. Class size ranged from four to eight students, and each class was divided into four components, which totaled six hours of didactic material in addition to a four-hour simulation lab. A precourse and postcourse evaluation was completed for each of the aEEG educational components. The topics included pathophysiology of HIE, development aEEG, and basic strip evaluation; in-depth aEEG voltage criteria and pattern recognition; and SWC and seizure identification (Tables 1–3). Product representatives were also included in the educational components, and they were responsible for educating the nursing staff regarding recommended product use, troubleshooting, and cleaning and storing of equipment.

TABLE 3 ■ Outline for aEEG Educational Program Components

Educational Component	Outline	Teacher Credentials
aEEG history, development, and basic strip evaluation	History What is an aEEG Classification systems Voltage classification Pattern classification Sleep–wake cycles Seizures Interpretation Reporting Outcomes Review of evidence Future research NICHD recommendations	NNP-DNP student
In-depth aEEG voltage and pattern recognition	Markers on aEEG to help identify voltage criteria and pattern criteria Voltage criteria: normal, moderately abnormal, and severely abnormal Pattern criteria: CNV, DC, BS, LV, and FT SWC identification Seizure identification Practice with multiple aEEG tracings to identify voltage, pattern, SWC, and seizures	NNP-DNP student
Simulation lab	All RNs who care for Level III infants are required to attend one session. All RNs must have completed the two cooling-related modules prior to attendance. All RNs must review protocol and appendices prior to arrival at clinical simulation. Review of algorithm and application using clinical scenarios and Sarnat scores and documentation Setup of aEEG machine Application of aEEG electrodes and documentation Medications used during TH aEEG pattern and voltage classification identification with use of teaching tool Impedance/artifact recognition and acceptable parameters and documentation Review of aEEG interpretation and documentation Verification of competencies	NNP-DNP student, unit CNS

Abbreviations: aEEG = amplitude-integrated electroencephalography; NICHD = National Institute of Child Health and Human Development; NNP-DNP = neonatal nurse practitioner-doctor of nursing practice; CNV = continuous normal voltage; DC = discontinuous; BS = burst suppression; LV = low voltage; FT = flat; SWC = sleep–wake cycling; RNs = registered nurses; TH = therapeutic hypothermia; CNS = clinical nurse specialist.

The simulation lab was taught using a format similar to what is used during Neonatal Resuscitation Program.[37] This approach gave the nurses in this unit the ability to practice their knowledge and skills in a real-life situation while also providing the opportunity to reflect, ask questions, and debrief on the learning process and contribute to what is needed to support further learning.

A follow-up survey was completed once the program concluded to assess the nurse's opinion of the program's effectiveness.

System Change

This program was initiated by conducting meetings with the primary stakeholders from the agency. These stakeholders included the neonatal nursing staff, respiratory therapy (RT) lead, medical staff, nursing manager, vice president of Nursing Services, perinatal clinical nurse specialist (CNS), and lead neonatal nurse practitioner (NNP). A "cooling team" was also developed, which consisted of ten neonatal nurses, the perinatal CNS, neonatal CNS, neonatologist, and the author. A few obstacles were encountered during the development of the systems change. Supplies necessary for the aEEG use took several weeks to arrive, delaying inclusion of manufacturer recommendations as well as manufacturer product education into the curriculum for aEEG interpretation.

The electronic record required changes for additional charting needs. The electronic record was changed to incorporate initiation time of the aEEG, initial baseline pattern, pattern noted during shift, changes in background pattern, and when notification of the provider took place. Thus, collaboration with information technology (IT) was

TABLE 4 ■ Schedule for Educational Program Components

Educational Component	Schedule
aEEG history, development, and basic strip evaluation	1.5 h of classroom didactic to cooling team members; rest of staff completed training online
In-depth aEEG voltage and pattern recognition	1.5 h of classroom didactic taught to entire unit in several sessions
Simulation lab	4 h of simulation taught to all staff members in several sessions

Abbreviation: aEEG = amplitude-integrated electroencephalography.

needed to make these changes which delayed education and simulation further.

Prior to implementation of this project, this hospital did not have a current policy and procedure (P & P) for use of aEEG. Best evidence was used to develop a P & P that included aEEG use, review of strips, documentation and reporting, and follow-up. The responsibilities of those involved in the care of these patients were also outlined. This P & P was created to provide detailed and consistent care for infants undergoing TH with the use of aEEG to create the best possible outcomes for this population.

Cooling Kit for Access of Necessary Equipment

Within the P & P, there is a detailed list of necessary equipment needed to effectively manage the aEEG during the cooling and rewarming process. However, during case reviews, it was established that there were some infants who were not identified as TH candidates until the last hour of eligibility,[38] which posed a significant concern for the group; this was identified as a deficiency within the plan. The importance of being able to work efficiently in that last hour of eligibility to set up the aEEG monitor required that many supplies be gathered from several different areas within the unit.

To solve this problem, a "cooling kit" was created that contained all of the identified materials necessary to set up the aEEG within one hour. The bag contained materials and a laminated restocking checklist and is kept in the designated "cooling" cabinet in the admit room. Members of the cooling team assisted in creating this list.

Neonatal Nursing Education: Program Implementation

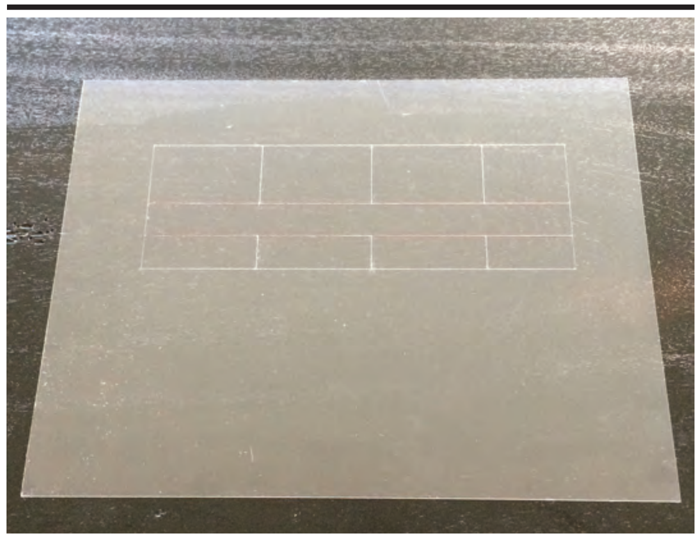
Nursing education was an incredibly important aspect of the implementation process of this program. Most of the nursing, medical, respiratory, and management staff had no experience with HIE, TH, or the use of the aEEG, which created stress and uneasiness within the unit regarding caring for this population. Therefore, it was necessary to create a broad and comprehensive nursing education program and training. The education program was provided to all full-time nursing staff and medical staff. Class size ranged from four to eight students, and each class was divided into three components, which totaled six hours of didactic material in addition to a four-hour simulation lab. A precourse and postcourse evaluation that was typically provided to nurses in this institution, to assess the accuracy of the nurse's interpretation and comprehension, was completed for several of the educational components. Each educational component was created in a manner that encouraged participation and focused on knowledge-based topics to allow the nurses to gain the necessary tools to care for this specific population. The topics included pathophysiology of HIE and overview of National Institute of Child Health and Human Development (NICHD) recommendations; case study reviews and application of TH eligibility algorithm; history, development of aEEG, and basic strip evaluation; in-depth aEEG voltage criteria and pattern recognition; and SWC and seizure identification (Tables 1–3). Product representatives were also included in the educational components, and they were responsible for educating the nursing staff regarding recommended product use, troubleshooting, and cleaning and storing of equipment.

The simulation lab was taught using a format similar to what is used during Neonatal Resuscitation Program.[37] This approach gave the nurses in this unit the ability to practice their knowledge and skills in a real-life situation while also providing the opportunity to reflect, ask questions, and debrief on the learning process and contribute to what is needed to support further learning.

Innovative Teaching Tool

An innovative teaching tool (Figure 1) was used during simulations to assist the nurse at the bedside in determining voltage classification and pattern classification based on the criteria created by al Naqeeb and colleagues[20] and Hellström-Westas and colleagues.[33] Based on these classification

FIGURE 1 ■ Innovative teaching tool for use with aEEG interpretation.



Abbreviation: aEEG = amplitude-integrated electroencephalography.

systems, a tool was designed so that, when placed over the aEEG monitor, a red line could be seen at 5 μV and 10 μV. Both classification systems use 5 μV and 10 μV as benchmarks for determining which category the voltage or pattern falls into. Lines were also created to designate each hour of aEEG recording for charting purposes. The tool is created with medical grade plastic that can be cleaned with the hospital-specific cleaning product. It can also be written on with erasable marker to aid the nurse in marking areas of concern or change. The nurses were first exposed to these two different criteria during didactic education in which several aEEG strips were presented. During the didactic portion of the education, the nurses were taught to first identify the lower margin of the aEEG strip and then the upper margin using the tool; from there, they were able to easily see what voltage the upper and lower margins used most of the time. They then could use the classification systems described in Table 1 to establish the tracing of the aEEG strip. The strips where then followed through the process of cooling and rewarming to demonstrate the evolution of brain function. The group was asked to first determine the voltage classification and then identify the pattern classification for each individual strip. They were then asked to decide if SWC were present and if seizure activity could be seen.

Learner Responses

Based on pretest and posttest questionnaires and evaluations of aEEG knowledge and interpretation skills, it was perceived that the development and dissemination of this program was well received by the nursing staff. The educational components of this program demonstrated improved learner knowledge, with pretest scores averaging 60 percent and posttest scores averaging 95 percent. These scores are only suggestive of short-term learner retention which indicates long-term follow-up and education should be provided. Course evaluations from participants were positive, providing feedback that encouraged continued education in similar format with more frequent simulation opportunities. Feedback from participants also demonstrated that the simulation experience increased comfort level and knowledge with this patient population and new equipment.

Future Work

Future work should include studies related to nurses' knowledge and skill retention as it relates to program development such as this. It should also include nurse satisfaction with educational training and materials to further develop educational material and knowledge retention.

Implications

Now that TH has become a standard of care in Level III NICUs, more and more units across the nation are incorporating cooling that includes the use of the aEEG. Many of these Level III NICUs are in community hospitals that might not have the experience that regional centers do, and that is why an evidence-based program such as this one can be easily implemented and sustained in other Level III NICUs. The collaborative development of this program, including the P & P, multifaceted educational materials, and ongoing education and skill retention, suggest that this program may be an effective approach to program implementation. Even though this program was developed for use in a community tertiary NICU, it has the capability of being adapted into other units and areas within the hospital.

CONCLUSION

The TH has become a standard of care in Level III NICUs. Although there are standard TH protocol recommendations based on large multicenter randomized controlled trials, it is important that an evidence-based approach for the education of the nursing staff is used in NICUs in which these therapies are introduced. The introduction of an educational program related to nursing care for infants who are treated with TH for HIE with aEEG may improve knowledge, comfort with the technology, and health care outcomes.

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