Screening for Critical Congenital Heart Disease in Newborns Using Pulse Oximetry

Evaluation of Nurses' Knowledge and Adherence

Donna J. Ryan, DNP, RN; Elizabeth Bradshaw Mikula, MSN, RN, CPN; Sarah Germana, MD; Susan G. Silva, PhD; Anne Derouin, DNP, RN, CPNP

ABSTRACT

PURPOSE: The purpose of this project was to evaluate the benefits of an online nursing education program addressing the significance and rationale of an evidence-based critical congenital heart disease (CCHD) screening protocol using pulse oximetry implemented on full-term newborns delivered at an academic obstetric referral center. The aim was to assess nurses' knowledge of the protocol and nurses' adherence to the protocol documentation before and after the education module was implemented.

SUBJECTS: Registered nurses working in the birthing center who completed the online knowledge tests and an education module.

DESIGN: A repeated-measures quality improvement study was conducted to assess nurses' knowledge of the evidence supporting CCHD screening by pulse oximetry and adherence to the correct documentation of the screening protocol before, immediately after, and 3 months following participation in an online education module.

METHODS: Nurses' knowledge of the CCHD screening protocol was determined by the number of correct answers on a 10-item online test administered before and after the education module. Adherence to correct documentation of the protocol before and after the education intervention was evaluated. The medical charts of 300 newborns delivered at the center with pulse oximetry readings performed after 24 hours of age and before discharge were randomly selected and reviewed.

RESULTS: A significant improvement in knowledge test scores was observed immediately after the education module (9.1 ± 1.0), relative to baseline (8.4 ± 1.2; paired $t = 3.02$, $P = .0046$). A significant increase in knowledge test scores measured at baseline, immediately after, and 3 months postintervention was also indicated ($F = 3.25$; $df = 2, 24$; $P = .0564$). Documentation of the protocol in the medical charts for the location of the readings significantly improved after the educational intervention (right hand: 28%, 83%, and 90%; right foot: 27%, 82%, and 89%; both $P < .0001$).

CONCLUSIONS: Providing education to staff before implementing new practice changes enhances their knowledge. Quality improvement monitoring is recommended to ensure nursing adherence to any practice change.

Key Words: congenital heart disease, critical congenital heart disease, pulse oximetry

Author Affiliations: *Duke University School of Nursing (Drs Ryan, Silva, and Derouin) and Duke University Medical Center Birthing Center (Dr Germana), Durham, North Carolina; and HCA Henrico Docors' Hospital (Ms Mikula), Richmond, Virginia.*

The authors declare no conflict of interest.

Correspondence: *Donna J. Ryan, DNP, RN, Duke University School of Nursing, 307 Trent Dr, Durham, NC 27710 (donna.ryan@duke.edu).*

DOI: 10.1097/ANC.0000000000000047

Congenital heart disease (CHD), a defect with the structure of the heart or with the flow of blood through the heart, is the most common birth defect among the most major anomalies.[1-6] Approximately 8 or 9 of every 1000 births (1%) have a form of CHD.[1-3] The prenatal diagnosis of CHD is made in only 50% of newborns with CHD.[3,6] Some forms of CHD cause few or no problems in the health, growth, and development of the infant.[7] According to the Centers for Disease Control and Prevention,[8] CHD accounts for 24% of infant deaths because of birth defects.

Critical CHD (CCHD) has been defined as congenital heart defects that require surgery or catheter insertion within the first year of life.[3] Critical CHD is a form of CHD that is usually associated with hypoxia in the newborn period and requires intervention during the first months of life.[7,9] Critical CHD is responsible for approximately 1 in 3 of all CHD or 2.5 to 3 of every 1000 births.[10] About 30% of newborns with CCHD may leave the hospital undiagnosed.[1] Therefore, the consequences of delaying treatment until the infant becomes critically ill are a much longer stay in the intensive care unit, a higher incidence of serious complications such as neurological impairment, and often higher operative mortality.[1,3]

BACKGROUND AND SIGNIFICANCE

In the United States, approximately 4800 (or 11.6/10,000) newborns every year have 1 of 7 critical congenital heart defects.[8] The 7 defects include transposition of the great arteries, hypoplastice left heart syndrome, total anomalous pulmonary venous connection, pulmonary atresia, tetralogy of Fallot, tricuspid atresia, and truncus arteriosus.[11] Newborns with undetected CCHD are discharged from hospitals as "healthy" only to return via the emergency department after becoming symptomatic at home such as poor feeding and/or cyanosis and apnea, or with more critical events such as heart failure or cardiogenic shock.[12] Symptoms frequently present after closing of the patent ductus arteriosus after nursery discharge.[13] In most cases of CCHD, the patent ductus arteriosus is the only way that oxygenated blood can mix with deoxygenated blood and it will need to remain open after birth. If the CCHD is not discovered before discharge, the baby will become distressed when the patent ductus arteriosus closes, and the birth defect may block the flow of blood out of the left or right side of the heart. Therefore, early discovery of CCHD before discharge can potentially improve the prognosis and lower the mortality rate of affected infants.[5,14-16]

EVIDENCE: LITERATURE REVIEW AND SYNTHESIS

Sufficient evidence exists to support a change in the current practice of CCHD screening by prenatal echocardiograms and physical examination to include screening by pulse oximetry after 24 hours of age and before hospital discharge. There are several studies that report the efficacy of pulse oximetry screening for CCHD. Wren and colleagues[14] reviewed charts for 690,215 live births over a 20-year period and found that 1 in 3 newborns with a potentially life-threatening cardiac malformation left the hospital undiagnosed.[14] de-Wahl Granelli and colleagues[4] compared 5 district hospitals in one health region in Sweden that screened 38,429 asymptomatic newborns with a cohort of surrounding hospitals that did not use screening by pulse oximetry. The study found that missed diagnosis occurred in 8% with screening but in 28% without screening.[4] These finding were confirmed by Meberg and colleagues[24] in Norway, who compared those hospitals that used pulse oximetry screening and those that did not. Critical CHD was detected before discharge in 44 of 50 newborns (88%) in hospitals that used pulse oximetry as compared with 37 of 48 newborns (77%) in the hospitals that did not use the screening. Performing a typical physical examination alone for CCHD led to almost 10 times more false-positive results compared with using similar screening protocols in Sweden and the United Kingdom.[11]

Mahle et al[3] reviewed 10 studies and a total of 51 098 infants. In an analysis of pooled studies of oximetry assessment performed at 24 hours of life, the estimated sensitivity for detecting CCHD was 69.6% and the positive predictive value was 47.0%. Sensitivity varied dramatically among studies from 0% to 100%. False-positive screens that required further evaluation occurred in only 0.035% of newborns screened after 24 hours.[3] Hoffman[1] reviewed 12 studies and found that despite considerable variation in the way data were gathered, about 30% (range, 13%-48%) of newborns with CCHD may leave the hospital undiagnosed. Thangaratinam and colleagues[17] screened 552 studies and identified 13 eligible studies with data from 229,421 newborns, and found that pulse oximetry is highly specific for detection of CCHD with moderate sensitivity. The overall sensitivity of pulse oximetry detection of CCHD defects was 76.5% (95% confidence interval [CI], 67.7-83.5). The specificity was 99.9% (95% CI, 99.7-99.9), with a false-positive rate of 0.14% (95% CI, 0.06-0.33). The false-positive rate for detection of CCHD was particularly low when newborns were screened after 24 hours from birth (0.05%; 95% CI, 0.02-0.12) versus before 24 hours (95% CI, 0.29-0.86).[17]

Pulse oximetry improves the ability to detect CCHD in newborns before they clinically decompensate rather than relying on physical examination alone.[3,6,12,18-20] Pulse oximetry screening is a painless, noninvasive test used to measure the percentage of oxygen saturation in the hemoglobin of arterial

blood and is widely used and accepted in clinical care.[7] The test is easily performed, is inexpensive, and requires little training of nursery personnel. Screening for CCHD costs less and is more readily available than screening that is currently being done for many other newborn conditions such as hypothyroidism.[7]

The Congenital Heart Disease Screening Program (CHDSP) Toolkit developed by Childrens' National Medical Center[7] in Washington, DC, promotes early detection of CCHD through the use of pulse oximetry performed after 24 hours of age, in the newborn nursery. Screening before 24 hours of age can lead to false-positive results because of the transition from fetal to neonatal circulation and stabilization of systemic oxygen saturation levels.

Critical CHD screening by pulse oximetry has been endorsed by the US Department of Health and Human Services, the Secretary's Advisory Committee on Heritable Disorders in Newborns and Children, the American Heart Association, the American Academy of Pediatrics, the American College of Cardiology Foundation,[21] the March of Dimes, and the National Association of Neonatal Nurses[22] as a potential screening test for early detection of CCHD. Although no national mandates for CCHD screening currently exist, most states have introduced or already passed legislation that promotes newborn screening for CCHD.[21,23]

The purpose of this project was to evaluate the benefits of an online education module (OLEM) addressing the significance and rationale of an evidence-based CCHD screening protocol using pulse oximetry implemented in a high-risk obstetric referral center on full-term newborns. The aim was to assess nurses' knowledge of the protocol and nurses' adherence to the protocol documentation before and after the education module was implemented.

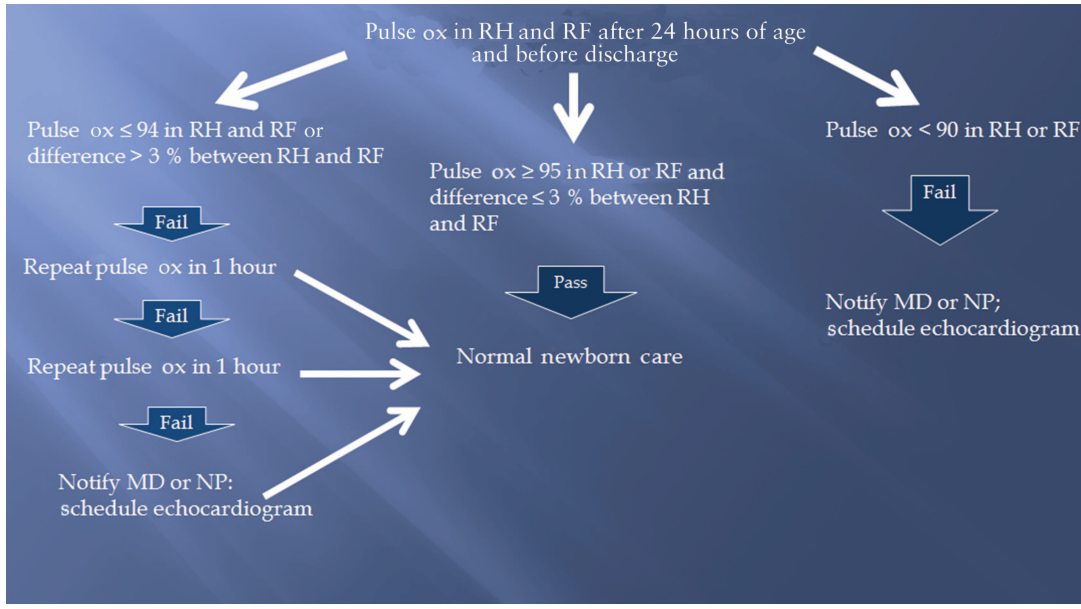
METHODS

Setting and Design

This quality improvement project was conducted in a 46-bed obstetric referral center within the tertiary medical center that delivers more than 3000 newborns per year. This center was one of the first hospitals in its state to implement the pulse oximetry protocol for CCHD screening. Figure 1 summarizes the CCHD screening protocol approved and implemented in the birthing center (BC). All 93 registered nurses working in the BC were invited to participate in the project. Nurse participation in the project was voluntary. Each BC nurse was assigned a personal identification number that was used to determine who completed the test at each time point. The quality improvement project was approved by the Medical Center institutional review board before initiating data collection.

A repeated-measures design was used to assess the impact of an *OLEM* intervention on nursing staff's knowledge of the evidence supporting pulse oximetry screening of all full-term newborns admitted to a BC at this southeastern academic hospital.

FIGURE 1.



Critical congenital heart disease screening protocol. Abbreviations: MD, medical doctor; NP, nurse practitioner; Pulse ox, pulse oximetry; RF, right foot; RH, right hand.

Assessments of the nurses' knowledge of the pulse oximetry protocol were conducted before, immediately after, and 3 months after completion of the OLEM. In addition, the medical charts of 300 full-term newborns delivered at the center with pulse oximetry readings performed after 24 hours of age and before discharge were randomly selected and reviewed to evaluate the extent to which adherence to CCHD screening protocol documentation was present in the newborns' charts. This retrospective review included 100 randomly selected charts for newborns at each time period delivered over a 1-month period: (*a*) before, (*b*) immediately after, and (*c*) 3 months after the OLEM to evaluate the sustainability of the information provided.

Figure 2 provides an overview of the time line for the different assessments. *Time 1* refers to the baseline assessments administered before the OLEM implemented on June 16 to July 15, 2012. *Time 2* indicates the point at which the OLEM and immediate postintervention assessments were provided. *Time 3* represents assessments completed 3 months after the OLEM. For chart reviews, each time point indicates the full newborn delivery period from which adherence data were collected.

Procedures

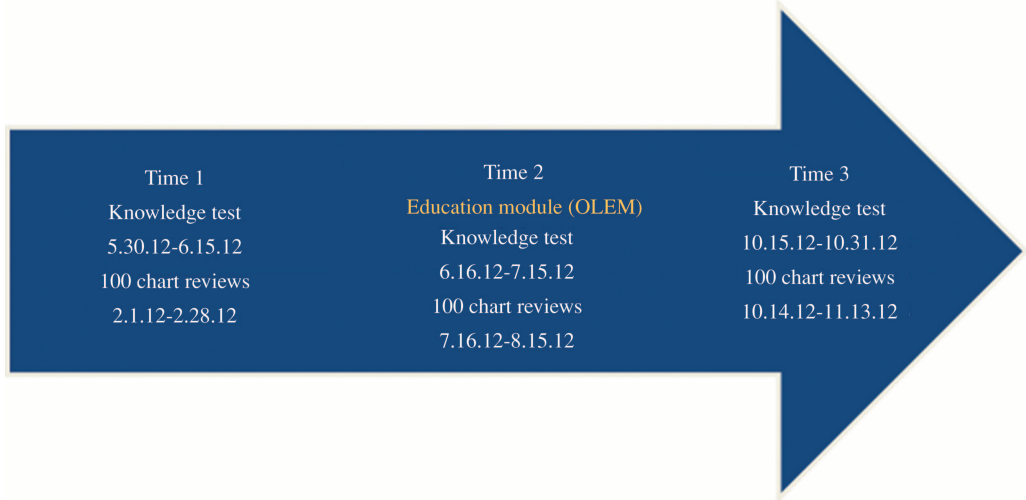
The CCHD screening protocol was approved by the BC's Clinical Practice Committee in the fall of 2011. All nurses in the BC were introduced to the new protocol at the November 2011 staff meeting. Posters, created by the nurse manager, with minimal guides and instructions, were displayed throughout the BC, in the staff workroom, the nursery, and all nursing stations. The nursing staff was required to read all of the revisions to the nursery protocols and sign off that they had reviewed them. The importance of the CCHD screening protocol was stressed to the nurses by nursing management through verbal communication as an evidence-based practice change.

The primary author met with BC nurse managers and interim clinical operations director several times, and the final proposal was accepted in April 2012. On approval of the project by the center administration, the 93 nurses working in the BC were invited to participate in this project designed to improve the nurses' understanding of the rationale and procedures for the evidence-based use of pulse oximetry to screen for CCHD. Full or partial participation in the project was voluntary.

REDCap, a secure Web-based electronic data collection software system, was used to administer and track completion of the OLEM, demographic information, and knowledge tests. The *time 1* baseline assessments were e-mailed to the 93 registered nurses, with a link to the online assessments that were available for 2 weeks. Each BC nurse was assigned a personal identification number that was included when inserting each BC nurse's e-mail address into REDCap. This was needed to determine which nurses completed more than one time point. A reminder e-mail was sent 1 week after the start of time 1 period to nurses who had not yet completed the survey.

At *time 2*, the OLEM and postintervention assessments were e-mailed to the 93 nurses regardless of whether or not they had completed the baseline assessments. The education program and immediate postintervention assessments remained available for 4 weeks. A reminder e-mail was sent 2 weeks following the start of the period to those potential

FIGURE 2.



Intervention and schedule of assessments. Abbreviation: OLEM, online education module.

participants who had not completed the OLEM and/or assessments. The *time 3* assessments were e-mailed to the 93 registered nurses 3 months after the OLEM was provided at 3 months after the end of time 2. The time 3 assessments were available for 2 weeks, and a reminder e-mail was sent 1 week after the start of time 3 period to nurses who had not yet completed the assessments.

A retrospective review of 300 medical charts for full-term newborns with pulse oximetry readings performed after 24 hours of age and before discharge was performed to evaluate adherence to the CCHD screening protocol documentation before and after the OLEM was implemented. For each time point indicated on Figure 2, a sample of 100 charts was randomly selected from the newborns delivered at the BC during the specified 1-month period.

Online Education Module

The OLEM intervention used portions of the CHDSP Toolkit. The Children's National Medical Center[7] granted copyright permission to use the CHDSP Toolkit as a resource for education and training nurses in the BC. The tool used for this project was reviewed by a panel of experts at Children's National Medical Center, including those in nursing education, biomedical engineering experts, and physicians. See Table 1 for description of the content provided in the OLEM.

A March 2012 consensus among the BC nurses found that they preferred to complete an OLEM rather than in-person presentation. This PowerPoint education module included slides and text without a voice component so that the participants could follow at their own pace. All information asked in the test item questions were provided in the content of the OLEM.

TABLE 1. Content of the Online Education Module

Significance and background of CCHD screening with pulse oximetry
Anatomy of a normal heart and fetal circulation
Significance of patent ductus arteriosus
Duct-dependent heart disease lesions
Placement of pulse oximetry probe
Need for baby to be quiet and monitor with a good waveform
The protocol states that screening should be performed after 24 hours of age
Documentation of the date, time, and location (right hand and either foot)
Importance of cleaning reusable probes
Recommendations for follow-up if a positive screen

Abbreviation: CCHD, critical congenital heart disease.

Assessments

Demographic Information

The demographic characteristics for the participating nurses were collected each time the nursing knowledge test was administered. Demographics included race, sex, age, education completed, years of nursing experience, years employed in the BC, and professional membership.

Knowledge Test

The participating nurses completed online knowledge tests at time 1, which took place approximately 2 weeks before the OLEM intervention; time 2, immediately after completing the OLEM; and time 3, approximately 3 months after completing the OLEM (see Figure 2). The knowledge test was designed to ascertain whether the nurses understood the evidence, rationale, and procedures for implementing pulse oximetry protocol to screen for CCHD. The same assessment of knowledge consisting of a 10-item multiple choice or true/false test was administered at all 3 assessment points. The number of correct items on each test was calculated. See Appendix for the item questions and correct answers in bold.

CCHD Screening Protocol Adherence

A retrospective review of medical charts for 300 full-term newborns with pulse oximetry readings performed after 24 hours of age and before discharge was conducted. More specifically, nursing notes and discharge summaries found in the electronic medical record (EMR) of each infant were examined for evidence of nursing documentation of the pulse oximeter readings as outlined by the protocol. The following indicators of nursing adherence to the pulse oximetry protocol were examined: (1) documentation of the date and time pulse oximetry readings were performed, (2) documentation of the location of the pulse oximetry probe (right hand and right foot), (3) documentation of the pulse oximetry readings for both locations, (4) documentation if there was a 3% or more difference between the 2 readings, and (5) documentation if the protocol was followed for a failed screening. Figure 2 presents the 1-month period for each documentation-adherence evaluation. For each adherence indicator, the absence (0) or presence (1) of correct documentation in the medical chart during each of 3 adherence time points was also recorded. The proportion of medical charts with correct documentation for each of these items was calculated.

Analysis Plan

Descriptive statistics were used to summarize the data from the demographic, knowledge test, and adherence data at each of the 3 time points. Nondirectional statistical tests were performed with the level of significance set at 0.05 for each test. Repeated-measures analyses were used to evaluate the effects of the OLEM on total correct answers for the knowledge test. For each adherence indicator, a χ^2 test was conducted to compare the proportion of the medical charts reviewed with correct documentation during each of the 3 assessment points. The Fisher exact test was performed as an alternative to the χ^2 test when the assumptions of the χ^2 test were not met.

RESULTS

The nursing knowledge test scores were evaluated by establishing 3 different analyses because of the fact that not all participating nurses completed all 3 assessments and some nurses did not participate in the baseline assessment at time 1 but did participate in assessment at later time points. The following analyses were created to better ascertain the nurses' knowledge of the protocol before the intervention as well as the short-term and longer-term effects of the OLEP.

- *Analysis 1:* Nurses who completed the baseline assessment at time 1.
- *Analysis 2:* Nurses who completed the baseline, OLEM, and the immediate postintervention assessment (times 1 and 2);
- *Analysis 3:* Nurses who completed the baseline assessment, OLEM, postintervention assessment, and the 3-month postintervention assessment (times 1, 2, and 3).

Among the 93 registered nurses invited to participate in the project, 52 (56%) completed the time 1 baseline assessment. Table 2 presents the demographics characteristics of the nurses in each analysis. The numbers of nurses in each analysis were 52, 38, and 25, respectively. For the 52 completing the baseline assessment at time 1, a sensitivity analysis composed of those who later participated in the time 2 or time 3 assessments did not reveal any significant demographic differences in the 3 analyses.

Analysis 1: Baseline Nursing Assessment

Fifty-two nurses completed the time 1 knowledge test. On average, the age of the nurses was 37.8 years. The number of years in nursing was 12.9 years, and the number of years working in the BC was 6.1 years. All of the participating nurses were female and most were white (64.7%), with most nurses having earned their bachelor's of science in nursing (64.7%). Table 3 indicates that the average number of correct items on the 10-item knowledge test was 8.3 (SD = 1.3; range, 5-10).

Analysis 2: Baseline and Immediate Postintervention Nursing Assessment

Thirty-eight nurses completed the baseline and the immediate postintervention assessments (times 1 and 2), representing 40.9% of the 93 nurses invited to participate and 73.1% of the 52 nurses who completed a baseline assessment. The mean number of correct items on the 10-item knowledge test at time 1 was 8.4 (SD = 1.2) and at time 2 immediately after reviewing the OLEM was 9.1 (SD = 1.0). A paired *t*-test was conducted to compare for pre- and post intervention difference in the number of correct items on the knowledge test. The mean "time 2 minus time 1" change score was significantly different from 0 ($t = 3.02$, $P = .0046$). The mean time 2 − time 1 change score was 0.7 (SD = 1.4; range, −4 to +4). Four nurses (10.5%) did worse, 14 (37%) performed the same, and 20 (53%) improved immediately after completing the OLEM. Table 3 shows the knowledge test score results for this analysis.

Analysis 3: Baseline Through the 3-Month Nursing Assessment

Table 3 presents the mean number of correct items on the 10-item knowledge test administered at each time point for the 25 nurses that participated in all 3 assessments. A mixed-effects regression model for repeated measurements was performed to evaluate change over the 3 time points for the 25 nurses. This trajectory analysis tended to show a slight positive increase in the number of correct answers on the knowledge test over time ($F = 3.25$; $df = 2, 24$; $P = .0564$). As Table 3 indicates, the number of correct items for the 25 nurses was 8.2 at baseline, 9.0 immediately after the OLEM, but dropped slightly to 8.7 at the 3-month assessment point.

Adherence to Documentation

Figure 3 presents the number of full-term newborns delivered at the center with pulse oximetry readings performed after 24 hours of age and before discharge from which the random sample of 100 medical charts was selected for the adherence assessment. Several newborns were transferred to the intensive care nursery, and the final sample size was n = 85 at time 1, n = 96 at time 2, and n = 88 at time 3.

Table 4 provides the frequencies and percentage of each sample with correct documentation of the date and time of pulse oximetry readings, the location of readings, if there was a 3% difference between the 2 readings, and if the infant passed or failed. Documentation of the date of the readings decreased from time 1 and time 2 and then increased at time 3 (71.4%, 43.2%, and 47.7%, respectively). Documentation of the time of the readings after 24 hours after birth also decreased from time 1 to time 2 to but then increased at time 3 (67.1%,

TABLE 2. Demographic Characteristics of Nurses for the 3 Analyses[a]

Characteristics	Analysis 1 (N = 52)	Analysis 2 (N = 38)	Analysis 3 (N = 25)
n with demographic data	51	37	24
Age, y			
Mean ± SD	37.8 ± 12.5	37 ± 12.7	38.4 ± 14.5
Range	21-66	21-66	21-66
Years in nursing			
Mean ± SD	12.9 ± 11.0	11.6 ± 10.7	12.3 ± 11.8
Range	0.5-39	0.5-39	0.5-39
Years at the birthing center			
Mean ± SD	6.1 ± 5.7	4.8 ± 4.7	5.2 ± 5.0
Range	0.3-25	0.3-14	0.3-14
Sex, n (%)			
Female	51 (100.0)	37 (100.0)	24 (100.0)
Race, n (%)			
White	33 (64.7)	23 (62.1)	15 (62.5)
African American	7 (13.7)	4 (10.8)	2 (8.3)
Hispanic/white	1 (2.0)	1(2.7)	1 (4.2)
Asian	6 (11.8)	5 (13.5)	4 (16.7)
Other	4 (7.8)	4 (10.8)	2 (8.3)
Education, n (%)			
Associate	13 (25.5)	9 (24.3)	7 (29.2)
Diploma	4 (7.8)	3 (8.1)	2 (8.3)
BSN	33 (64.7)	25 (67.6)	15 (62.5)
MSN	1 (2.0)	0 (0.0)	0 (0.0)
Professional nursing organization	12 (23.5)	6 (16.2)	3 (12.5)

Abbreviations: BSN, bachelor's of science in nursing; MSN, master's of science in nursing; OLEM, online education module.

[a]Analysis 1: Nurses who completed the baseline assessment at time 1; Analysis 2: Nurses who completed both the baseline, OLEM, and the immediate postintervention assessment (times 1 and 2); Analysis 3: Nurses who completed the baseline assessment, OLEM, postintervention assessment, and the 3-month postintervention assessment (times 1, 2, and 3).

29.5%, and 43.2%, respectively). Documenting the location of the readings, however, improved over time (right hand: 28.2%, 83.2%, and 89.8%, respectively; right foot: 27.1%, 82.2%, 88.6%, respectively).

Barriers to Implementation of the OLEM

There were barriers to the implementation of the OLEM. The BC nursing leaders were worried about nursing compliance if the nurses perceived the CCHD screening protocol as extra work; therefore, they did not approve adding a separate form to document the pulse oximetry readings, instead choosing to have the information documented in the existing EMR. The leadership allowed staff nurses to complete the surveys only during their work hours and not before or after their shift. Continuing education units were not offered for this OLEM, because the offering did not meet the minimum time length requirements. The primary author did not know most of the BC staff nurses, which also could have affected their willingness to participate in the quality improvement project.

DISCUSSION/IMPLICATIONS

Timely recognition of CCHD improves outcomes and reduces the consequences of delayed treatment.

TABLE 3. Nursing Knowledge Test Results for the 3 Analyses[a]

Assessment	Analysis 1 (N = 52)	Analysis 2 (N = 38)	Analysis 3 (N = 25)
Time 1 assessment			
Mean ± SD	8.3 ± 1.3	8.4 ± 1.2	8.2 ± 1.3
Minimum-Maximum	5-10	6-10	6-10
Time 2 assessment			
Mean ± SD	NA	9.1 ± 1.0	9.0 ± 1.0
Minimum-maximum	NA	6-10	6-10
Time 3 assessment			
Mean ± SD	NA	NA	8.7 ± 0.9
Minimum-maximum	NA	NA	7-10

[a] *The means and SDs for the number of correct items on the 10-item knowledge test is reported; NA indicates not applicable to the analysis.*

Nurses performing CCHD screening in newborns need to acknowledge and support this evidence-based practice. But first, nurses need to learn and understand the significance and rationale of the evidence supporting CCHD screening by pulse oximetry and adherence to the correct documentation of the screening protocol. The BC nurses preferred an OLEM over an in-person presentation because of their limited time to complete during their work hours. Eighty-nine one-half percent of the respondents did the same or better after the OLEM, which indicates that the OLEM did increase nurses' knowledge and understanding of the screening protocol. The adherence findings illustrate an improvement in nursing documentation of the location (right hand and right foot) of the pulse oximetry readings at each time point but a decrease in the documentation of the date and time of the readings. When the CCHD screening protocol was a new practice, the nurses initially were diligent in documenting the pulse oximetry readings in the EMR, either in the nursing notes or in the discharge summary. Documentation in the nursing notes was automatically date and time stamped, as opposed to the discharge summary, where the nurses have to add the date and time when they document. Once the protocol was in place and after the education module was offered, the practice in the BC was to document the pulse oximetry readings only in the discharge summary. After the primary author met with the BC leadership to disseminate the project findings, the leadership confirmed that the expected documentation practice is to document in the nursing notes section of the EMR. Because more than half of the nurses did not complete the OLEM, they may not have realized the significance in documenting the date and time of the readings.

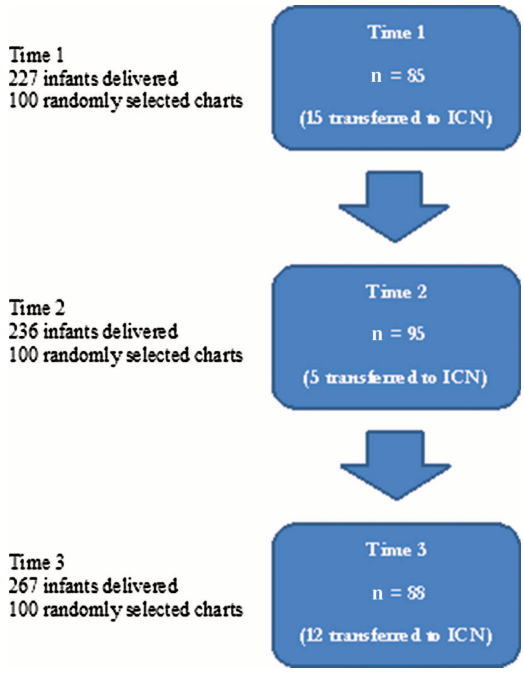
The findings of this study are limited to the convenience sample of one BC in southeast United States and may not be representative of other obstetric units throughout the country. Because participation was voluntary, not all nurses completed the online surveys, causing a small sample

TABLE 4. Adherence: Percentage of the Medical Chart Sample With Correct Documentation

	Time 1 (N = 85)		Time 2 (N = 95)		Time 3 (N = 88)	
Variable	Frequency	%	Frequency	%	Frequency	%
Date	60	71.4	41	43.2	42	47.7
24 hours	57	67.1	28	29.5	38	43.2
RH	24	28.2	79	83.2	79	89.8
RF	23	27.1	78	82.1	78	88.6
Pass	81	95.3	93	97.9	87	98.9

Abbreviations: 24 hours = pulse oximetry reading documented 24 hours after delivery; Date, date pulse oximetry reading documented; Foot = pulse oximetry documented on foot; Pass = documentation that infant passed pulse oximetry screening; RH = pulse oximetry documented on right hand.

FIGURE 3.



Adherence documentation samples.
Abbreviation: ICN, intensive care nursery.

size in which the results cannot be generalized. Offering both online and in-person education also could have increased participation. The fact that the knowledge test included only 10 items limited the extent to which the nurses' understanding of the rationale and procedures could be improved by the educational intervention. However, the test was intentionally brief in an effort to increase the practical application of the instrument in the clinical setting.

CONCLUSION

An OLEM to provide the knowledge and significance of a practice change is one effective method in ensuring that nurses adhere to evidence-based practice. This education module could be replicated as an online or in-person presentation in other clinical settings seeking to implement CCHD screening. The CHDSP Toolkit was a valuable resource for this OLEM and is available to anyone who requests it. The decrease in correct documentation of the date and time of the pulse oximetry readings after the OLEM illustrated the need for continuous monitoring and education reinforcement. The findings from this project support the need for organizations to provide sufficient instruction and education before implementing new protocols or changes in practice. Quality assurance efforts in monitoring pulse oximetry readings could ensure that the readings are performed after 24 hours of age.

References

1. Hoffman J. It is time for routine neonatal screening by pulse oximetry. *Neonatology*. 2011;99(1):1-9.
2. Thangaratinam S, Daniels J, Ewer AK, Zamora J, Khan KS. Accuracy of pulse oximetry in screening for congenital heart disease in asymptomatic newborns: a systematic review. *Arch Dis Child Fetal Neonatal Ed*. 2007;92(3):F176-F180.
3. Mahle WT, Newburger JW, Matherne GP, et al. Role of pulse oximetry in examining newborns for congenital heart disease: a scientific statement from the AHA and AAP. *Pediatrics*. 2009;124(2):823-836.
4. de-Wahl Granelli A, Wennergren M, Sandberg K, et al. Impact of pulse oximetry screening on the detection of duct dependent congenital heart disease: a Swedish prospective screening study in 39,821 newborns. *BMJ*. 2009;338:a3037.
5. Ewer AK, Middleton LJ, Furmston AT, et al. Pulse oximetry screening for congenital heart defects in newborn infants (PulseOx): a test accuracy study. *Lancet*. 2011;378(9793):785-794.
6. Koppel RI, Druschel CM, Carter T, et al. Effectiveness of pulse oximetry screening for congenital heart disease in asymptomatic newborns. *Pediatrics*. 2003;111(3):451-455.
7. Children's National Medical Center. Congenital Heart Disease Screening Program Toolkit. http://www.childrensnational.org/PulseOx/. Published 2011. Accessed November 2, 2011.
8. Centers for Disease Control and Prevention. Pulse oximetry fact sheet: screening for critical congenital heart disease. http://www.cdc.gov/ncbddd/pediatricgenetics/documents/CCHD-factsheet.pdf. Published 2012. Accessed October 12, 2012.
9. Martin GR, Bradshaw EA. Sensitivity of pulse oximetry for detection of critical congenital heart defects in newborn infants higher than that of antenatal ultrasound with few false positives. *Evid Based Med*. 2012;17(2):57-58.
10. Hoffman J, Kaplan S. The incidence of congenital heart disease. *J Am Coll Cardiol*. 2002;39(12):1890-1900.
11. Kemper AR, Mahle WT, Martin GR, et al. Strategies for implementing screening for critical congenital heart disease. *Pediatrics*. 2011;128(5):e1259-e1267.
12. Stokowski LA. Screening for congenital heart disease: one step closer. *Adv Neonatal Care*. 2010;10(6):274.
13. Cuzzi S, Bradshaw EA. The road to universal pulse-oximetry screening: are we there yet? *Pediatrics*. 2011;128(5):e1271-e1272.
14. Wren C, Reinhardt Z, Khawaja K. Twenty-year trends in diagnosis of life-threatening neonatal cardiovascular malformations. *Arch Dis Child Fetal Neonatal Ed*. 2008;93(1):F33-F35.
15. Mellander M, Sunnegårdh J. Failure to diagnose critical heart malformations in newborns before discharge--an increasing problem? *Acta Paediatr*. 2006;95:407-413.
16. Ewer AK, Furmston AT, Middleton LJ, et al. Pulse oximetry as a screening test for congenital heart defects in newborn infants: a test accuracy study with evaluation of acceptability and cost-effectiveness. *Health Technol Assess*. 2012;16(2):v-xiii, 1-184.
17. Thangaratinam S, Brown K, Zamora J, Khan KS, Ewer AK. Pulse oximetry screening for critical congenital heart defects in asymptomatic newborn babies: a systematic review and meta-analysis. *Lancet*. 2012;379(9835):2459-2464.
18. Valmari P. Should pulse oximetry be used to screen for congenital heart disease? *Arch Dis Child Fetal Neonatal Ed*. 2007;92(3):F219-F224.
19. Hoke TR, Donohue PK, Bawa PK, et al. Oxygen saturation as a screening test for critical congenital heart disease: a preliminary study. *Pediatr Cardiol*. 2002;23(4):403-409.
20. Meberg A, Brugmann-Pieper S, Due R Jr, et al. First day of life pulse oximetry screening to detect congenital heart defects. *J Pediatr*. 2008;152(6):761-765.
21. Mahle WT, Martin GR, Beekman RH, Morrow WR. Endorsement of health and human services recommendation for pulse oximetry screening for critical congenital heart disease. *Pediatrics*. 2012;129(1):190-192.
22. National Association of Neonatal Nurses. Universal newborn screening for congenital heart disease. http://www.nann.org/advocacy/agenda/universal-newborn-screening-for-congenital-heart-disease.html. Published 2013. Accessed March 15, 2013.
23. Newborn Foundation and Coalition. CCHD screening map. http://cchdscreeningmap.org/. Published 2013. Accessed October 12, 2012.
24. Meberg A, Andreassen A, Brunvand L, et al. Pulse oximetry screening as a complementary strategy to detect critical congenital heart defects. *Acta Paediatr*. 2009;98(4):682-686. doi: 10.1111/j.1651-2227.2008.01199.x

APPENDIX. Nursing Knowledge Test

1. The following can affect the accuracy of the pulse oximetry (pulse ox) reading:
   a. Movement
   b. Cold extremities or shivering
   c. Crying
   d. Bilirubin lamps and surgical lights
   e. **All of the above**
2. One clean, disposable pulse ox probe can be used on up to 5 patients.
   a. True
   b. **False**
3. All of the following can affect the accuracy of the pulse ox reading except:
   a. Placing the pulse ox probe on the same extremity that you are taking the blood pressure
   b. Performing the pulse ox test while the infant is crying
   c. Using a clip on the finger of an infant
   d. **Infant skin color or jaundice**
4. Pulse ox screening will detect all forms of CHD.
   a. True
   b. **False**
5. The screening guidelines state that pulse ox should be performed on:
   a. The right hand
   b. One foot
   c. **Both a and b**
   d. Neither a nor b
6. Pulse ox screening should be performed when the infant is of what age?
   a. Less than 8 hours
   b. Between 8 hours and 18 hours
   c. **Greater than 24 hours**
   d. Less than 24 hours
7. An infant's pulse ox readings should be reported to the physician or nurse practitioner caring for the infant if:
   a. Pulse ox readings are greater than 94% for both right hand and right foot and there is greater than a 3% difference between the 2nd and 3rd measures each separated by 1 hour
   b. Pulse ox readings are less than 94% for both right hand and right foot or there is greater than a 3% difference between the 2nd and 3rd measures each separated by 1 hour
   c. Pulse ox reading is less than 90% for either or both the right hand and right foot
   d. **All of the above**

The following questions are related to determining the 3% difference of the right hand and foot pulse oximetry readings. For the following questions, please determine whether the answer is pass or fail.

8. The first screen the upper extremity (UE) sat is 100% and lower extremity (LE) saturation is 96%
   a. Pass
   b. **Fail**
9. Upper extremity saturation is 99% and lower extremity sat is 98%
   a. Pass
   b. **Fail**
10. Upper extremity sat is 89% and lower extremity sat is 87%
    a. Pass
    b. **Fail**

Note: Correct answers are in bold.