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Pulse Oximetry Screening for Critical Congenital Heart Disease in Planned Out of Hospital Births and the Incidence of Critical Congenital Heart Disease in the Plain Community

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Abstract

Objective—This study evaluated pulse oximetry screening (POS) for critical congenital heart disease (CCHD) in planned out of hospital births with special attention to births in Plain communities (Amish, Mennonite and similar).

Design—Wisconsin out of hospital births in 2013 and 2014 were evaluated. Care providers were supplied with and trained in the use of pulse oximeters for CCHD screening. State records were reviewed to identify deaths and hospital admissions due to CCHD in this population.

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Results—Detailed information on POS was available in 1,616 planned out of hospital births. 799 were from the Plain community. 1,584 babies (98%) passed their POS, 16 infants (1%) failed, and 16 (1%) were not screened. 5 infants from the Plain community had CCHD, 3 were detected by POS.

Conclusion—POS for CCHD can be successfully implemented outside the hospital setting and plays a particularly important role in communities with high rates of CCHD and where formal prenatal screening is uncommon.

INTRODUCTION

Infants with congenital heart disease may be missed by both prenatal detection and physical examination in the immediate newborn period.[1, 2, 3, 4, 5] Critical Congenital Heart Disease (CCHD), or congenital heart diseases in which intervention is needed in infancy, is not uncommon[6] and delays in diagnosis can lead to significant morbidity and mortality [7, 8, 9, 10] Pulse oximetry screening (POS) has been shown to decrease the rate of missed CCHD [11, 12, 13, 14] and decrease the associated mortality due to CCHD in hospital born infants [11]. Limited information is available on the utility of POS to detect CCHD has not yet been demonstrated in the out of hospital (OOH) birth population.[15]

Many factors complicate the use and evaluation of POS in the OOH birth population. Definitions of CCHD in the literature are not uniform, and with any newborn screening test, the yield of POS is affected by the prenatal detection rate. Accepting the variable definitions of CCHD and variable prenatal detection rates, sensitivities between 49.06% - 62.07% and specificities of 99.16% - 99.82% [11, 12, 13] have been reported using the recommended protocol[16]. The reported positive predictive values (PPV) range from 13.33% - 35.90% and negative predictive values (NPV) range from 99.16 – 99.82%. In these studies, the false positive rate ranges from 0.18% - 0.81% and the overall failure rates from 0.22% - 0.97%.[11, 12, 13]

Universal POS for CCHD was recommended by the US Secretary of Health and Human Services in 2011 and is now considered the standard of care for hospital born infants. [16, 17] In 2013 the AAP also recommend POS for planned home births.[18] Reasoning behind this recommendation includes less frequent use of prenatal diagnostic testing, more limited periods of postnatal observation, and higher rates of missed CCHD in the OOH birth population. [9] In addition, OOH births may be attended by a wide variety of care providers with a range of experiences and skills including physicians, licensed and unlicensed midwives, and community birth attendants.

In Wisconsin, women from Plain communities (Amish, Mennonite, and similar backgrounds) frequently opt for home deliveries and account for a significant proportion of the OOH birth community. The risk of CCHD may be higher in the Plain population. Ellis Van Creveld Syndrome (EVCS) is substantially more common in the Lancaster County (PA) Amish[19] than the general population, is associated with a high incidence of congenital heart disease[19, 20, 21, 22], and might contribute to an increase in CCHD in the Amish community.

This study sought to evaluate the use of POS in OOH births in Wisconsin and to evaluate the incidence of CCHD in this population with special attention to births in Plain communities.

METHODS

This study of Wisconsin OOH births was performed from January 2013 through December 2014. This study was part of a larger project to implement and assess POS screening for CCHD funded by Health Resources and Services Administration (HRSA) Demonstration Grant H46MC24057. A detailed explanation of the Wisconsin Screening Hearts in NEwborns (SHINE) Project has been previously reported.[15] The functions of the Wisconsin SHINE project were reviewed by the University of Wisconsin Health Sciences Institutional Review Board and determined to be quality assurance measures and not human subject research.

For the purposes of this study, OOH births included those at the family home, those taking place at birthing centers, and births that occurred at the homes of midwives or community birth attendants. Initially, the Wisconsin SHINE Project provided pulse oximeters and training to members of the Wisconsin Guild of Midwives. Enrollment of licensed midwives began in late 2012 and continued throughout the study. The project later expanded to include unlicensed midwives, Plain community birth attendants, and members of the mainstream health care system involved in OOH births. A total of 83 health care personnel were trained in the use of pulse oximetry, of whom 8 were Plain community birth attendants, 12 were public health nurses, 2 were unlicensed English midwives, and 1 was a physician. The remaining 60 were licensed members of the Wisconsin Guild of Midwives.

A total of 73 pulse oximeters were deployed during the study. Participants offered POS to families on a voluntary basis. Recommended screening time was between 24 and 48 hours after birth, and oxygen saturation was measured in the right hand and either foot with a handheld pulse oximeter and reusable probe (Masimo, Irvine, CA). Pass / fail results were determined as per the two-site oximetry protocol described by Kemper et al.[16]

Participants reported screening results and clinical outcomes on a standardized questionnaire. The standardized questionnaire included timing of screening, pass / fail, number of attempts, and basic demographic data such as zip code and maternal age. Mothers were identified as being part of a Plain community or not, but further differentiation within the Plain communities was not recorded. As membership in a Plain community is not routinely recorded on other Wisconsin documents, this designation could only be determined for home births within the SHINE project. Members of the Plain community often refer to people outside their community as "English". We used the designation of "English" to identify those families known to be outside the Plain community.

CCHD was defined as one of the twelve diagnoses mentioned in the 2009 AAP evaluation of POS [23] (hypoplastic left heart syndrome, pulmonary atresia, tetralogy of Fallot, total anomalous pulmonary venous return, transposition of the great arteries, tricuspid atresia, truncus arteriosus, coarctation of the aorta, double outlet right ventricle, Ebstein's anomaly, interrupted aortic arch, and single ventricle) . Information on infants with other forms of

congenital heart disease was not systematically recorded and could not be fully determined from the data gathered.

Infants who passed the POS required no further evaluation. A protocol was established for failed screening that included contacting a hotline that would respond to questions regarding the algorithm or data collection methods, and would provide consultation and clinical support for any infant failing the screen. Access to an on-call pediatric cardiologist was available to the participating midwives at all times.

As part of the Wisconsin SHINE project, the charts of all patients under one year of age admitted to the American Family Children's Hospital (Madison) or the Children's Hospital of Wisconsin (Milwaukee) with 1 of the 12 CCHD diagnoses were reviewed in detail to determine the mechanism of diagnosis, if POS had been performed, the place of birth, and if the baby was a member of a Plain community. These are the only centers in Wisconsin which provide interventional catheterization and surgical treatment for CCHD. A prior analysis of Wisconsin births suggested that 13.6% of critically ill neonates would be transferred out of state for continuing care,[24] primarily to Minnesota.

State death records and hospital discharge records were also reviewed to identify any babies with CCHD that might have otherwise been missed. This information was combined with the information reported by participants to maximize ascertainment of infants with CCHD.

Statistical analysis: Categorical data were summarized in terms of frequencies and percentages. Data measured on a continuous scale were summarized using means +/- standard deviations. Chi-square or Fisher's exact test was used to compare categorical subjects' characteristics between cohorts (Plain community vs. Non-Plain community). The nonparametric Wilcoxon rank sum test was utilized to compare maternal age between cohorts. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value for CCHD screening were calculated and reported along with the corresponding 95% confidence intervals. All P-values are two-sided and $P<0.05$ was used to determine statistical significance. Data analysis was conducted using SAS software (SAS Institute Inc., Cary NC) version 9.4.

RESULTS

Demographics

According to the Wisconsin Department of Health Services, there were 130,756 births reported on blood cards in the state in 2013 and 2014. There were a total of 2,753 OOH births from 2013 – 2014, representing 2.1% percent of all births. The number of reported OOH births increased from 1,297 (1.93%) in 2013 to 1,456 (2.19%) in 2014. Detailed information on POS was available from the SHINE Project on 1,616/2,753 (58.7% percent) of 2013 and 2014 OOH births.

Of the 1,616 infants, there were 842 boys and 774 girls. 799 were from the Plain community, 775 were English, and in 42 the baby's background was not reported.

There were a number of differences between the Plain and English populations. Prenatal ultrasound was performed in 557 English infants (71.9%) but in only 250 (31.3%) of Plain infants ($p < 0.0001$). Notably, many of the ultrasounds in the Plain community were limited to assessments for gestational age and fetal position with no intent to screen for congenital heart defects. The average maternal age in the English population was 30.9 +/- 5.0 years and 29.8 +/- 6.3 years in the Plain population ($p = 0.0003$).

Plain infants were screened later than English infants. 229 Plain infants (28.7%) had POS at > 48 hours, compared to 42 (5.4%) of the English infants ($p < 0.0001$). Age at screening was not reported for 26 Plain infants, 9 English infants, and 6 infants whose background was unknown. Screening was declined in 14/799 (1.8%) of Plain births and 2/775 (0.3%) English births ($p=0.0069$).

As outreach to the Plain community increased, births to Plain families in the study exceeded those of English families. In 2013, Plain births represented 203/503 (40.4%) of births evaluated. This increased to 596/1113 (53.5%) in 2014 (Table 1).

Screening Results

Of the 1,616 babies, 1584 passed, 16 failed, and 16 weren't screened. The sensitivity of the screening for CCHD was 60% (95% CI: 23-88%), with a specificity of 99.2% (95% CI: 98.4-99.4%). The positive predictive value was 18.8% (95% CI: 7-43%) and negative predictive value was 99.9% (95% CI: 99.3-99.9%) (Table 2).

There were significant differences in the results of screening between the Plain and English populations. 773/799 of the Plain infants (97%) passed, compared to 770/775 (99%) of the English infants ($p = 0.0004$).

Of the 12 Plain infants who failed their POS, 3 were found to have CCHD. These infants were diagnosed with 1) type 1 tricuspid atresia, 2) type 2 tricuspid atresia with an interrupted aortic arch, and 3) double inlet left ventricle with transposition and coarctation. There were 2 false negatives in the Plain population, one infant had an isolated coarctation of the aorta and the other had a coarctation of the aorta and ventricular septal defect. All five infants with CCHD in the study population were Amish, none of which had EVCS. Two Plain infants with significant congenital heart disease were identified. One baby with EVCS and an unbalanced atrioventricular canal failed their pulse oximetry screening and one baby with heterotaxy and severe pulmonary valve stenosis passed their pulse oximetry screening. The POS results of these seven infants are given in Table 3.

Of the 3 English infants who failed their POS, none had CCHD, but two had sepsis. In these two babies, failed POS prompted early diagnosis and treatment. One of the babies in whom Plain status was unknown failed, but did not have CCHD.

Review of CCHD admissions, hospitalization and death records, identified no babies with CCHD in the 1,137 home births that were not part of the SHINE project.

DISCUSSION

Our study demonstrates that POS screening can successfully be implemented outside of a hospital setting, with 58.7% of all OOH births in Wisconsin participating in POS screening as part of this study from 2013 – 2014 despite a rolling enrollment through the study period. The sensitivity, specificity, PPV, and NPV of POS screening in our study are similar to those reported in hospital born infants (Table 4). [11, 12, 13]

Both infants with coarctation of the aorta in this cohort passed their POS. Prior studies of hospital born babies have also shown low sensitivity for coarctation of the aorta ranging from 30-43%.[11, 12, 13]

In this study, there was a high burden of CCHD in the OOH birth community, which appears to be was borne primarily by the Plain community. Our ability to fully assess the burden of CCHD in the OOH and Plain clothes communities is limited by the nonuniform recruitment of midwives and other OOH providers and our inability to determine whether births outside the SHINE Project were from Plain or English families.

This is the first large study of POS that includes Plain births. Although a higher incidence of congenital heart disease is often assumed in Amish and other Plain communities, there is no published literature on the incidence of CCHD in the Plain community. Although an increased incidence of congenital heart disease in Plain communities is often attributed in part to EVCS, none of the infants with CCHD in this study carried this diagnosis. As those forms of congenital heart disease beyond the twelve CCHD diagnoses were not systematically recorded, their incidence cannot be evaluated by this study.

This study also demonstrated an increasing number of Plain births. This may be due in part to increased reporting of Plain births as a consequence of the increased outreach to the community. However, an increasing Plain population is consistent with anecdotal evidence and the experience of clinicians in the state of Wisconsin, suggesting that the Plain population may in fact be increasing.

Pulse oximetry screening detects more infants in settings with a lower prenatal diagnosis rate. [11, 13] In the OOH birth population, prenatal ultrasounds were performed in 71.9% of English women and only 31.3% of Plain women. Thus, in this population of women with limited prenatal screening, POS becomes even more useful and clinically significant. POS may also be more palatable for patients who decline prenatal ultrasounds and other testing, as it is minimally invasive and inexpensive.

There was wide variation in the reported time of POS. This was particularly true for the Plain community birth attendants, with a significant portion of screening performed more than 48 hours after birth (229 Plain infants versus 42 English infants). Ideally, screening should take place after 24 hours to minimize false positive results[25]. The preferred time for screening is between 24 and 48 hours of life, to maximize sensitivity while allowing early detection and intervention prior to symptoms. Delayed POS in Plain infants puts them at greater risk for clinical complications of undetected CCHD. We hypothesize that there is greater practice variation in Plain community birth attendants, resulting in greater variation

in data collection in the Plain community. Additionally, some very conservative Plain families may be less likely to allow midwives and nurses from outside the community into their homes, and often decline to have postpartum visits on Sundays creating additional barriers for POS screening and less precisely timed screening.

CONCLUSION

Pulse oximetry screening is of particularly high value in screening for CCHD in high risk populations such as the Plain community and can be effectively introduced into the care of babies born outside a hospital setting.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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	Plain	English	Not Specificed	Total
2013	203	286	14	503
2014	596	489	28	1113
Total	799	775	42	1616

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	CCHD	No CCHD	Total	
Fail	3	13	16	PPV 18.8%
Pass	2	1582	1584	NPV 99.9%
Total	5	1595	1600*	
	Sensitivity	Specificity		
	60%	99.2%		*16 Refused

	POS Measurements	Age at POS
Critical Congenital Heart Disease		
Type 1 Tricuspid Atresia	87/87	45 hours
Type 2 Tricuspid Atresia, IAA	91/92, 90/91, 91/93	24 hours
DILV, D-TGA, Coarctation	88/84	24 hours
Coarctation	95/95	>48 hours
Coarctation, VSD	96/96	>48 hours
Significant Congenital Heart Disease		
Unbalanced Atrioventricular Canal	86/84	8 hours
Heterotaxy, Severe Pulmonary Stenosis	96/96	>48 hours

	SHINE	Zhao	Ewer	DeWahl
	US	China	UK	Sweden
Year	**2016**	**2014**	**2011**	**2009**
Sensitivity	60%	58.70%	49.06%	62.07%
Specificity	99.18%	99.70%	99.16%	99.82%
PPV	18.75%	35.90%	13.33%	20.69%
NPV	99.87%	99.89%	99.86%	99.97%
Failure Rate	1.00%	0.43%	0.97%	0.22%
FP Rate	0.81%	0.25%	0.81%	0.18%