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Pulse Oximetry During the First 24 Hours as a Screening Tool For Congenital Heart Defects

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Abstract

Introduction: Although screening for congenital heart defects (CHD) relies mainly on antenatal ultrasonography and clinical examination after birth, life-threatening cardiac malformations are often not diagnosed before the patient is discharged.

Aim: To assess the use of routine pulse oximetry in the delivery room and at 24 hours postpartum, and to study its feasibility as a screening test for CHD.

Material and Methods: In this prospective study, all infants born in "Cuza Voda" Maternity Hospital, Iasi, Romania, were enrolled over a thirteen-month period. Preductal oximetry was assessed during the first hour, and postductal oximetry was evaluated at twenty-four hours postpartum. Data were then analyzed to establish the sensitivity and specificity of pulse oximetry, as a screening test for CHD.

Results: 5406 infants were included in the study, with a mean gestational age of 38.2 weeks and a mean birth weight of 3175 grams. During the first minute, blood oxygen saturation varied between 40% and 90% and at 24 hours of life, it ranged between 90% and 100%. Following oximetry assessment, 14 infants with critical CHD were identified. Blood oxygen saturation values in infants with CHD were lower throughout the entire period of evaluation. Pulse oximetry had good sensitivity and specificity at 1 hour (Se=87.5%, Sp=95.5%) and 24 hours (Se=92.5%, Sp=97.4%) for the diagnosis of CHD. Blood oxygen saturation values at one minute, 1 hour and 24 hours are strong discriminative parameters for the early diagnosis of CHD.

Conclusion: Routine pulse oximetry during the first 24 hours postpartum represents an early indicator of CHD to facilitate timely intervention. Pulse oximetry provides excellent sensitivity and specificity and has tremendous potential as a standard screening test for CHD during the first 24 hours of life.

Keywords: congenital heart disease, pulse oximetry, screening

■ INTRODUCTION

Congenital heart defects (CHD) are among the more common categories of congenital malformations and an important cause of early childhood mortality [1,2]. Globally each year, eight per 1000 live born infants are diagnosed with a form of CHD [3], and the incidence of critical CHD (CHD leading to death or needing major surgery during the first year of life is 3 per 1000 [4-6].

Although remarkable progress was made during the last 20 years concerning the diagnosis and treatment of CHD, there are still 25% [7] to 39% [8] infants diagnosed with this condition after leaving the maternity ward, at a mean age of 6 weeks.

Prenatal diagnosis by ultrasonography can often detect major CHDs, but these defects are often missed in Romania, due to the lack of adherence of pregnant women to a program of prenatal visits to the obstetrician.

Pulse oximetry is a useful, inexpensive, non-invasive method for routine monitoring of the neonate, and it

can also be used for raising suspicion of CDHs. Pulse oximetry can detect hypoxemia, missed during a clinical examination before it becomes profound enough for cyanosis to be observed. Early detection of CHDs can significantly reduce the risk of sudden cardiovascular collapse [9,10] and allows timely intervention, whether by palliation with prostaglandin E_1, or by surgical repair.

Moreover, monitoring of blood oxygen saturation during the first day can guide the physician towards the diagnosis of other conditions, mainly respiratory, but also infectious or metabolic.

The American Academy of Pediatrics recommends pulse oximetry screening for CHD between 24 and 72 hours postpartum [11]. We aimed to ascertain whether an even earlier diagnosis can be made with a low risk of false-positive results. The purpose of this study was to examine the use of peripheral blood oxygen saturation monitoring in neonates during the first hour postpartum and at 24 hours of life, as a means of the early diagnosis of CHD.

◼ MATERIAL AND METHODS

A prospective study of neonates born in the "Cuza Voda" Clinical Hospital of Obstetrics and Gynecology from December 1, 2012, to December 31, 2013, was undertaken. Preductal pulse oximetry was carried out on all newborns, in the delivery room, by placing the sensor on the right hand or wrist. Blood oxygen saturation was monitored throughout the first hour postpartum and logged at 1, 5, 15, 30 and 60 minutes. The values provided by Dawson et al [12]. were used as the reference range. Values of 95% or higher at one hour were considered normal. Values of less than 95% mandated further investigations. Postductal blood oxygen saturation was recorded at 24 hours, with the sensor being attached to the foot of the infant until a stable reading was obtained. If values of less than 95% were recorded, an echocardiogram was performed, regardless of any clinical signs.

The entire process of monitoring was conducted using Nellcor™ (Covidien, Ireland) or Masimo™ (Masimo, Switzerland) pulse oximeters. Collected data were analyzed with the purpose of designing the receiver operator characteristic (ROC) curve for pulse oximetry as a screening test for CHD.

Critical CHDs were defined as, D-transposition of the great arteries, coarctation of the aorta, Tetralogy of Fallot, hypoplastic left heart syndrome, pulmonary stenosis, aortic stenosis, and truncus arteriosus. Other defects, such as persistent foramen ovale or isolated ventricular septal defect, were considered non-critical CHDs.

The prediction of SpO_2 for CHD was studied through the assessment of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV), as well as through the design of the ROC curve and the analysis of the area under the curve (AUC), as a reference parameter for the strength of prediction. To assess its discriminative capability to detect CHD, the sensitivity and specificity of pulse oximetry was estimated when used as a diagnostic tool. PPV and NPV were used to describe the accuracy of pulse oximetry.

The ROC curve conveyed the relationship between sensitivity and specificity for pulse oximetry.

All calculations were made using SPSS for Windows, version 20.0.0, Chicago, Illinois. Statistical significance was set α = 0.05.

The study was approved by the "Cuza Voda" Hospital's Ethics Committee.

◼ RESULTS

During the 13-month study period, there were 5406 infants born in the "Cuza Voda" Maternity Hospital. The infants had gestational ages between 24 and 43 weeks, with a mean of 38.2 ± 2.0 SD and birth weights between 600 and 5000 grams, with a mean of 3175 ± 590 SD. 608 (11.2%) of the infants were born preterm.

Apgar scores at 1 minute were between 1 and 10, with a median value of 9. At 5 minutes, Apgar scores were between 2 and 10 and at 10 minutes, they were between 3 and 10. Both at 5 and 10 minutes, median values for the Apgar score were 9 (Table 1).

87.7% of the newborns required no resuscitation in the delivery room, 10.7% needed simple methods of resuscitation such as tactile stimulation and free-flow oxygen, and 1.6% needed complicated resuscitation, including positive-pressure ventilation, chest compressions and medication.

At one minute postpartum, median blood oxygen saturation was 65% (IQR 62-70%). At one hour, blood oxygen saturation was 100% (98-100%), and at 24 hours, values of 100% (99-100%) were detected (Table 2). Median values at 5 and 15 minutes were slightly lower than expected (81% and 94%, respectively).

According to gestational age, median preductal blood oxygen saturation values at 1 minute were 66% (64-70%) in term and post-term infants, whereas in preterm newborn were 61% (55-67%). At 24 hours of age, term infants had postductal oximetry values of 100% (99-100%) and preterm infants had blood oxygen saturation of 98% (98-100%) (Table 3).

Following pulse oximetry readings and echocardiography, a total of 87 CHDs (1.6%), 62 in term newborns and 25 in preterms, were identified. (Fig. 1).

Blood oxygen saturation values are significantly lower in neonates with CHD at all times in the first 24 hours, compared to those without CHD, regardless of gestational age.

Table 1. Characteristics of the patients

	Mean value	SD	Min	Max
Gestational age (wk)	38.2	2.0	24	43
Birth weight (g)	3175	590	600	5600
Apgar 1min	8.4	1.1	1	10
Apgar 5min	8.5	1.2	2	10
Apgar 10min	8.7	1.0	3	10

Table 2. Oxygen saturation values at different times after birth

		Mean SpO2	SD	Min	Max
	SpO2_1'	65.6	7.0	30	90
	SpO2_5'	80.0	8.1	40	99
preductal	SpO2_15'	92.5	4.9	55	100
	SpO2_30'	97.0	2.5	70	100
	SpO2_1h	98.8	1.6	74	100
postductal	SpO2_24h	99.5	1.1	75	100

Table 3. Oxygen saturation values in term or post-term vs. preterm newborns

			Means SpO2	SD	Min	Max
Term/post-term	preductal	1'	66.4	6.3	34	90
		5'	80.8	7.4	55	99
		15'	92.9	4.3	70	100
		30'	97.2	2.2	82	100
		1h	99.0	1.4	88	100
	postductal	24h	99.6	0.9	90	100
Preterm	preductal	1'	60.1	9.5	30	83
		5'	74.2	10.3	40	98
		15'	88.7	7.6	55	100
		30'	95.3	3.6	70	100
		1h	97.8	2.6	74	100
	postductal	24h	98.6	1.9	75	100

84% of CHDs (73 cases) were categorized as non-critical and 16% (14 cases) as critical. Critical CHD were: 3 cases of pulmonary stenosis, 2 cases each of Tetralogy of Fallot, D-transposition of the great arteries, coarctation of the aorta and truncus arteriosus, and 1 case each of hypoplastic left heart syndrome, single ventricle, and aortic stenosis. We did not find in our study atrioventricular defects, total anomalous pulmonary venous return, or pulmonary atresia with an intact interventricular septum.

Of the 4736 term newborns, 98.7% had no CHD, 1.1% (52) had non-critical CHD and 0.2% [10] had critical CHD. Of the 583 preterm infants, 95.9% had no CHD, 3.4% [21] were found to have non-critical CHD and 0.7% [4] had critical CHD.

Blood oxygen saturation values differed significantly among the three groups. In the group without CHD, blood oxygen saturation was 100% (98-100%) at 1 hour and 24 hours, and in the group with non-critical disease, oximetry values were 98% (97-100%) at 1 hour and 100% (98-100%) at 24 hours, whereas in infants with critical CHD, lower values were recorded at both 1 and 24 hours - 92% (88-98%) and 94% (90-98%), respectively (Fig. 2).

Preterm infants, regardless of the presence or absence of heart defects, had significantly lower blood oxygen saturation, both when compared to normal ranges and the values of term infants. Also, preterm infants with CHD had lower values compared to their peers without CHD at all times.

The results of the analysis showed good sensitivity and specificity at 1 hour (Se=87.5%, Sp=95.5%) and 24 hours (Se=92.5%, Sp=97.4%) (Fig. 3). Whereas the NPV was high at all time periods (80.6%-98.9%), PPV was low during the first 30 minutes, but rose to 70% at 1 hour and peaked at 77.5% at 24 hours. (Fig. 4).

We found significant AUCs throughout the examined time periods (0.71-0.86), with a good compromise between sensitivity and specificity, thus ascertaining that, both during the first hour and at 24 hours of life, pulse oximetry is accurate enough as an indicator of CHD (Fig. 5).

According to our calculations, preductal pulse oximetry at 1 hour and postductal pulse oximetry at 24 hours are useful discriminative parameters for the presence of CHD and, thus, can be used for the postnatal screening for CHD.
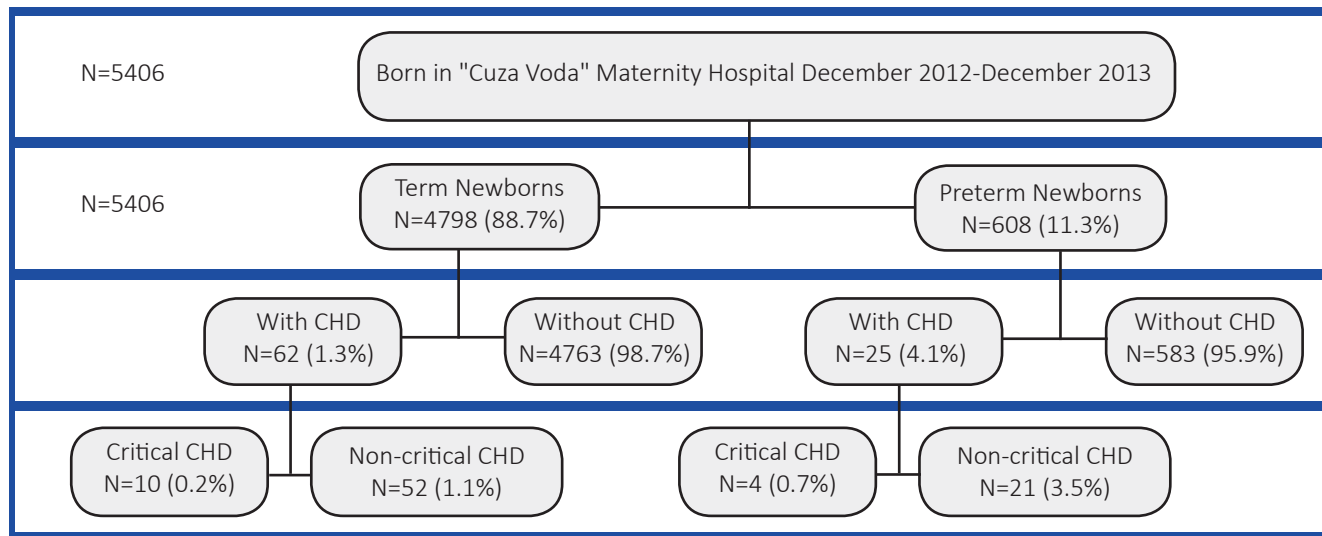
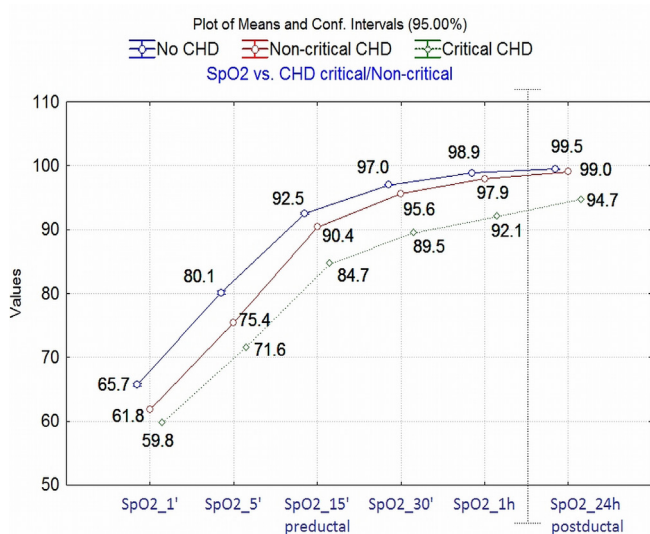**Fig. 1. Presence and type of CHD in infants born in a 13-months period**

Fig. 2. Oximetry values in infants with critical CHD vs. non-critical CHD vs. no CHD

◾ DISCUSSION

Congenital heart defects (CHD) have a substantial impact on infant mortality and childhood morbidity, accounting for more than 3% of all infant deaths and leaving long-term sequelae in survivors. Prenatal diagnosis of CHD, as well as a diagnosis in the neonatal period, can often be missed.

In 2009, the American Heart Association and the American Academy of Pediatrics issued a joint statement recommending routine pulse oximetry for all newborns before hospital discharge, but not in the first 24 hours, to improve the rate of detection of critical CHDs [6].

Oximetry values, documented during the first hour of life, can be influenced by multiple factors such as mode of delivery, gestational age, placement of the sensor, type of pulse oximeter used, or the administration
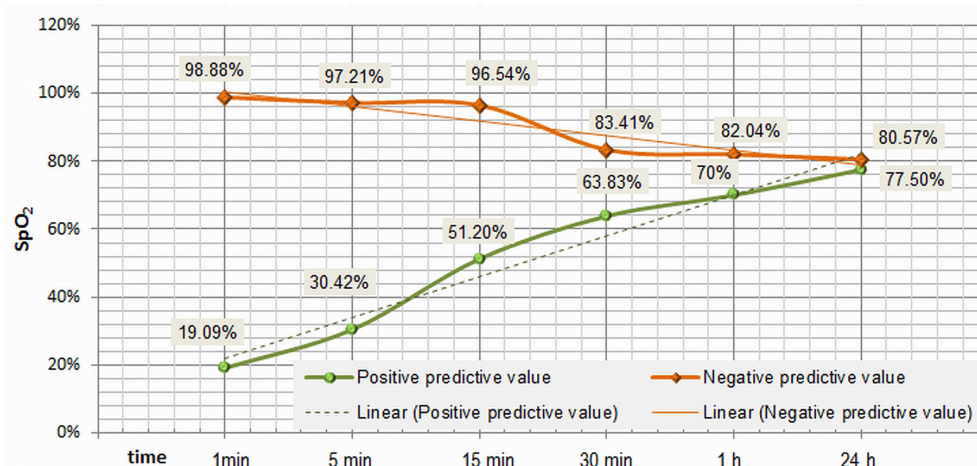

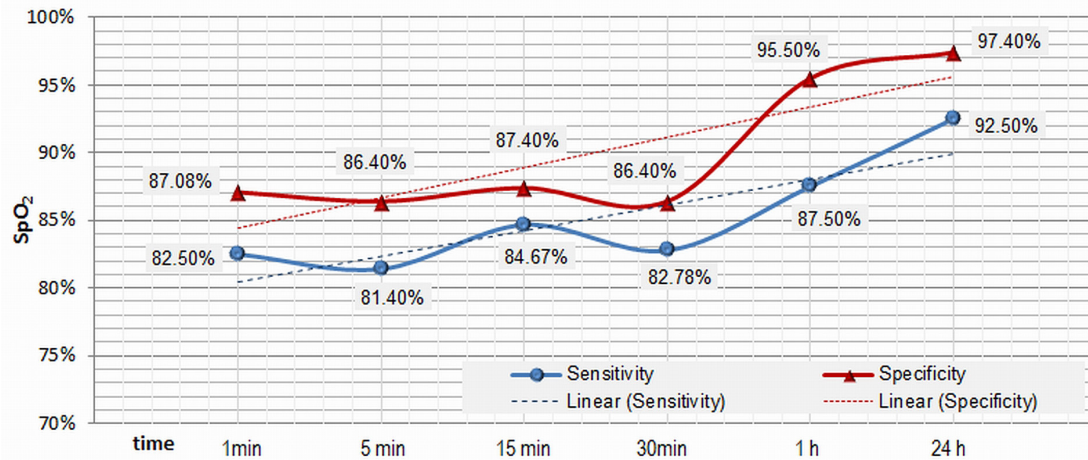**Fig. 3. Positive and negative predictive values of pulse oximetry**

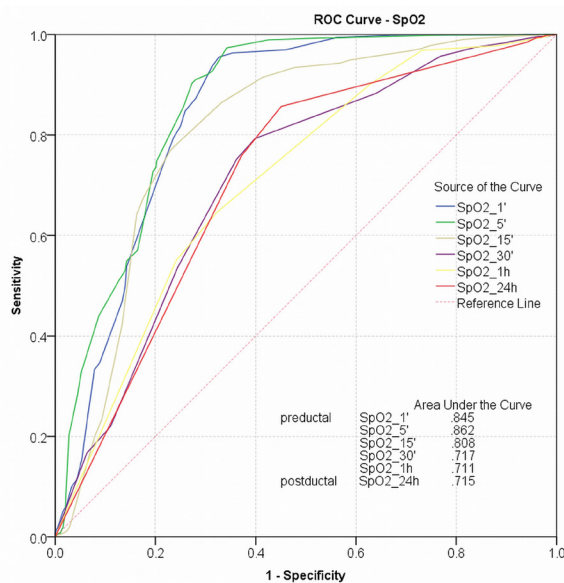**Fig. 4. Sensitivity and specificity of pulse oximetry**

Fig. 5. The ROC curve for neonatal pulse oximetry

of oxygen during resuscitation [13]. Preterm infants seem to take longer to establish a peripheral capillary oxygen saturation (SpO_2) greater than 90% [14], which was in accordance with the results of the present study. While term newborns have a mean SpO_2 of 93% at 15 minutes, preterm infants have a mean SpO_2 of 89%.

Detection of CHD by pulse oximetry in the delivery room is confounded by the possibility of persistent ductus arteriosus and thus of overlooking ductal-dependent CHD. Oximetry in the first 24 hours also has a slightly higher incidence of false positive results due to transient pulmonary hypertension or retention of lung fluid [10]. On the other hand, postductal pulse oximetry assessed at 24 hours or later has been shown to be accurate in detecting CHD [15-17].

A pulse oximetry screening study for congenital heart defects in newborn infants found a sensitivity of 72-75% in the first 12 hours, specificity of 99% throughout the first day and an excellent negative predictive value, similar to prenatal ultrasound [18]. Sendelbach et al. found that pulse oximetry screening at four hours postpartum did not improve detection of critical CHD beyond clinical assessment, and they did not endorse routine pulse oximetry in otherwise healthy neonates [19]. The major difference between this study and the others was the time of SpO_2 readings, four hours postpartum in their study compared to 24 hours or longer in other reported studies.

Our study proved excellent sensitivity and specificity throughout the periods of evaluation. To convey the relationship between sensitivity and specificity we elaborated the ROC curve and we expressed the global specificity of pulse oximetry by the area under the curve (AUC). The larger the AUC, the more precise is the test. In a meta-analysis, Thangaratinam et al [20]. found a similar ROC curve to the one obtained in the current study, with high sensitivity and specificity, but reported a lower rate of false-positive results if the pulse oximetry was performed after 24 hours of age. Indeed, in our study, the PPV was low at 30 minutes (conveying a high probability of false positive results), but was already 70% at one hour and higher at 24 hours.

Pulse oximetry can be of limited value in infants with poor peripheral perfusion, cardiac arrhythmias or environmental factors. The main limitation of pulse oximetry as a screening method of CHD is the risk of false negative results. The use of preductal and postductal blood oxygen saturation difference may further improve the detection of critical CHDs [21].

■ CONCLUSIONS

Pulse oximetry has been proven to be a feasible assessment for all levels of maternity hospitals, as it is inexpensive, easy to use with minimal training and acceptable to both parents and caregivers [3,9,22].

Pulse oximetry during the first 24 hours postpartum can be considered indicative of CHD, thus allowing early diagnosis and timely therapeutic intervention. The sensitivity and specificity of pulse oximetry, as well as its low cost and high compliance by both parents and health care personnel, warrant its use as a screening method for the identification of CHD.

■ AUTHOR DISCLOSURE STATEMENT

The authors report no conflicts of interest.

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