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Original Research Article

Role of pulse oximetry screening for detection of life threatening congenital heart defects in newborn

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Abstract

Prospective study included babies born at maternity hospital in sulaimany and babies born in private hospitals and referred to pediatric neonatal care unit in the first day of life for optimizing screening performance with pulse oximetry for detection of life threatening CHD. The study period was from 1 October 2012 to 1 march 2013. During that period 2371 live babies born. Out of these new born babies 2181 were enrolled in the study. The remaining newborns were excluded because they were premature, and the majority of them are hypoxic at birth due to immaturity of respiratory center which might lead to high false positive rate of POS. (Pulse oximetry screening). The POS for both hands and one foot were obtained within the first 3-6 hours of life. When post ductal saturation was below 90% it was considered as positive screening, while saturation between 90-95% and the difference between pre and post ductal saturation more than 3% the baby was provisionally considered to be screening positive, but a repeat measurement was performed. Babies with three repeated positive Measurements were arranged to have an echocardiogram performed in the same day according to the study protocol. The following information of each infant was recorded: Gestational age, age at echocardiography done, gender, birth weight, mode of delivery, Apgar score at 5 minutes, any association like IDM, IUGR, trisomy and any associated clinical presentation like murmur, cyanosis, tachypnea ,apnea and grunting. The main outcome in this study is measure of sensitivity, specificity, positive and negative predictive value of POS. Among 100 baby with positive POS, CHD was detected in 45 babies (45%) 12 babies were classified as major CHD and 33 babies as minor CHD. In 19 patient of all 45 patient there were additional clinical finding that might have prompted an echocardiographic evaluation: heart murmur (8), cyanosis (10), trisomy 21 (8). Of these 12 patients with major CHD 6 of them (50%) were asymptomatic at the time of POS. POS was true negative in 2078, true positive in 45 patients, false negative in 3 patients, and false positive in 55 and 28/55 of the false positive rate with POS had other pathology. And false positive rate with pulse oximetry screening is (55/2081) = 2, 6%. Sensitivity, specificity, positive and negative predictive value for POS in detection of major CHD were 80%, 97.29%, 17.9% and 99.80%, respectively. Our study showed that pulse oximetry screening of all well babies in maternity units is practically feasible with a minimum use of time, and that it significantly improves detection of life threatening congenital heart disease at an early stage. A significant number of newborns with critical congenital heart defects that have not been detected prenatally can be identified at an asymptomatic stage, before clinical deterioration occurs. This makes it possible to avoid cardiogenic shock in these patients before hospital discharge.

Keywords: Pulse oximetry, Echocardiography, Screening, Congenetal, Heart defect

INTRODUCTION

Congenital heart defect with a critical lesion are at risk of acute Cardiovascular collapse or death. At least 18 distinct types of CHD are recognized, with many anatomical variations (Lloyd-Jones et al., 2009).

Most newborns with a CHD can be diagnosed using echocardiography, However, if such defects are not

detected sufficiently early then severe hypoxemia, shock, acidosis and death are potential sequelae. Timely recognition of these conditions is likely to improve outcome and therefore the evaluation of screening strategies to enhance early detection is of importance (Tikanoja, 1995).

Major CHDs resulting in death or requiring invasive intervention (surgery or cardiac catheterization) during infancy are the lesions in which early detection by screening is most likely to improve outcome. We have further divided this group into two subcategories: critical and serious. Critical lesions are most likely to present in the first few days or weeks of life, usually as a result of closure of the ductus arteriosus (Mitchell et al., 1971).

Wren et al in their study defined critical CHDs in accordance with a previously published UK categorization (Wren et al., 2008) to include all potentially life-threatening duct-dependent conditions plus infants dying or undergoing invasive procedures (surgery or cardiac catheterization) within the first 28 days of life, although it is accepted that death from undiagnosed CHDs can occur after that age. Serious CHDs are defined as those defects not classified as critical that result in death or invasive intervention within 12 months of age.

The prevalence of major defects remains essentially unchanged at around 2.5 per 1000 live births (Lloyd-Jones et al., 2009; Hoffman and Kaplan, 2002; Mitchell et al., 1971). Critical lesions have an estimated incidence of 1–1.8 per 1000 live births (Wren et al., 2008; Barrington, 2009; Richmond et al., 2002) and this group accounts for between 15% and 25% of all CHDs, depending on the definitions used (Wren et al., 2008; Mahle et al., 2009).

Potentially life-threatening, critical CHDs, most of whom are asymptomatic at birth (Barrington, 2009) and in whom deterioration or death can occur before the condition is recognized (Abu-Harb et al., 1994).

Echocardiography is likely to have significant limitations as a screening tool, mainly because of the high false positive (FP) rate (Knowles et al., 2005; Mahle et al., 2009), but also as a result of cost and lack of availability of trained personnel to perform the examinations.

The rationale for pulse oximetry screening is based on the fact that hypoxaemia is present, to some degree, in the majority of CHDs. This may result in obvious cyanosis; however, mild degrees of hypoxaemia cannot be detected by clinical observation, even by experienced clinicians (O'Donnell et al., 2007). The difficulty is exacerbated in infants with pigmented skin (Mahle, 2008).

These findings have led to exploration of the possibility that pulse oximetry may be useful in detecting hypoxaemia associated with CHDs in apparently healthy newborns, and a number of studies have been published that have used pulse oximetry as a screen for CHDs in this group (Richmond et al., 2002; (Bakr and Habib, 2005; Hoke et al., 2002; Koppel et al., 2003; Reich et al., 2003; De Wahl Granelli et al., 2005; Rosati et al., 2005; Sendelbach et al., 2008; Meberg et al., 2008; De Wahl Granelli et al., 2009; Arlettaz et al., 2006).

Patients and methods

Prospective study included babies born at maternity hospital in Suleimany and babies born in private hospitals and referred to pediatric neonatal care unit in the first day of life for optimizing screening performance with pulse oximetry. The study period was from 1 October 2012 to 1 march 2013. During that period 2371 live babies born. Out of these new born babies 2181 were enrolled in the study. The remaining newborns were excluded because they were premature. Pulse oximeter screening was performed using B3-GIMA portable pulse oximeter with a neonatal OxiMax adhesive sensor. An accuracy of ±2% for the measurement of functional oxygen saturation (SpO2) was stated by the manufacturer. Two dimensional and Doppler (spectral and color) echocardiography examinations were obtained by same operator for positive screening patient using a commercial instrument with 3VC and 7VC MHz transducers (adjusted according to patient chest wall thickness) Acusons Cypress, USA made, supplied by Siemens company.

The POS for both hands and one foot were obtained within the first 3-6 hours of life. The probe was secured to the wrist or palm and to the sole of the foot, following a random order. The same oximeter was used for all three sequential measurements. To avoid movement artifacts, the pulse was observed until a good waveform was obtained. It usually required 3-5 minutes for all 3 measurements to be performed. The parents were informed, but no written consent was obtained On enrolment in the study, the following information of each infant was recorded: Gestational age, age at echocardiography done, gender, birth weight, mode of delivery, Apgar score at 5 minutes, any association like IDM, IUGR, trisomy and any associated clinical presentation like murmur , cyanosis, tachypnea ,apnea and grunting.

When post ductal saturation was below 90% it was considered as positive screening while saturation between 90-95% and the difference between pre and post ductal saturation more than 3% the baby was provisionally considered to be screening positive, but a repeat measurement was performed. Babies with three repeated positive Measurements were arranged to have an echocardiogram performed the same day according to the study protocol. When oxygen saturation above 95 % is define as normal and no further action is done. This protocol is shown on figure 1 below. POS results were recorded and statistics were performed on the data using SPSS 17, version for Windows. (Figure 1)

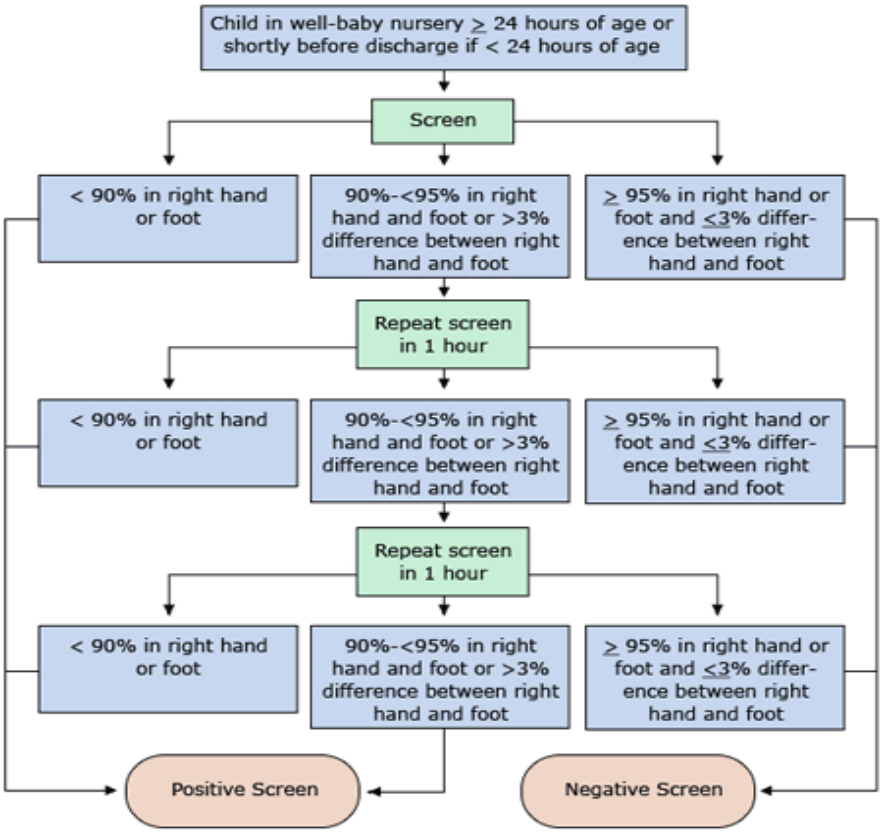

Figure 1 (Kanper et al., 2011). Algorithm for pulse oximetry screening for CHD.

Table 1. Base line characteristic of study population

Variable	No.
Gestational age	
Full term	92(92%)
Post term	8(8%)
Gender	
Male	47 (47%)
Female	53 (53%)
Apgar score at 5 minute	
Below 7	21 (21%)
Above 7	79 (79%)
Mode of delivery	
c/s	59 (59%)
NVD	41 (41%)
Family history of CHD	4 (4%)
Age at Echo done:	
Before 24 hour	7 (67%)
After 24 hour	33 (33%)
Antenatal diagnosis	0
IDM	9 (9%)
Trisomy	8 (8%)
IUGR	10 (10%)

RESULT

During the study period of five months, data from 100 babies with positive POS were recorded and analyzed. The median age at the time of echocardiography was (12 hour range from 1-3 days). Table 1 summarizes the

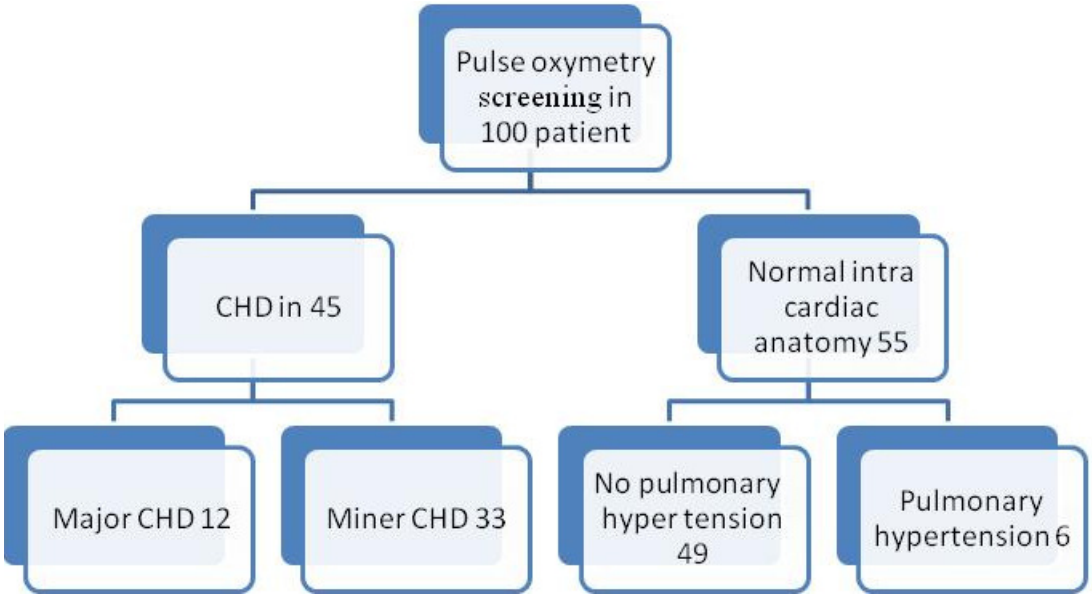

Figure 2. Echo graphic finding in 100 patients with positive pulse oximetry screening

Table 2. Type of congenital heart disease detected by pulse oximetry screening.

Group of diagnosis	N
Major CHD	**12**
TGA	2
TOF	2
TA	1
HLHS	1
PA	2
AVSD	2
COA	2
Minor CHD	**33**
Isolated PDA *	5
Mixed PDA **	8
VSD	8
ASD	10
PS	2

* Isolated PDA means PDA without other CHD.
** Mixed PDA means with ASD in 5 patient and VSD in 4 patients.

baseline demographic characteristics of the study population.

ACHD was detected in 45 babies (45%) 12 babies were classified as major CHD and 33 babies (33%) as minor CHD. An overview of the echocardiographic findings in the 100 screening-positive patients is given in (Figure 2), and the diagnoses are listed in (Table 2).

In 19 patient of all 45 patient there were additional clinical finding that might have prompted an echocardiographic evaluation: heart murmur (8), cyanosis (10), trisomy21 (8).

A separate analysis was performed for the 12 patients with major CHD (Table 3), 6 of these 12 patients (50%) were asymptomatic at the time of POS.

POS was true negative in 2078, true positive in 45 patients, false negative in 3 patients, (TA in1 patient, PDA in 1 patient and isolated VSD in 1 patient) and false positive in 55.

POS was false-positive related to the diagnosis of CHD in 55 newborns (healthy $n = 27$, persistent pulmonary hypertension of the newborn $n = 6$, sepsis $n = 13$, RDS =4, birth asphyxia =5). And false positive rate with pulse oximetry screening is (55/2081) = 2, 6%

A positive pulse oximetry screening gives a (P=0.003) of having major congenital heart disease.

The specificity, sensitivity, positive predictive value,

Table 3. Clinical findings in patients with major congenital heart defects (n = 12).

Cyanosis	Heart murmur	Asymptomatic	N	Major CHD
1	0	1 (50%)	2	TGA
0	1	1 (50%)	2	TOF
0	0	1 (100%)	1	Tricuspid atresia
0	1	0	1	HLHS
2	0	0	2	Pulmonary atresia
0	0	2 (100%)	2	AVSD
1	1	1 (50%)	2	COA
		6 (50%)	12	Total

Table 4. The performance of screening methods in the detection of major congenital heart disease in newborn infants.

Performance	Pulse oximetry
Sensitivity	80%
Specificity	97.29%
Positive predictive value	17.9%
Negative predictive value	99.80%
False-positive rate (%)	2.6%
No of true positives	12 (major CHD)
No of false negatives	3
No of false positives	55
No of true negatives	2078

and negative predictive value of pulse oximetry screening for major CHD were shown in (Table 4)

Sensitivity, specificity, positive and negative predictive value for POS were 80%, 97.29%, 17.9% and 99.80%, respectively.

DISCUSSION

On knowing that about 0.8-1 babies per 1000 live births have an immediately life threatening cardiac malformation, and 30% of such infants leave hospital without the malformation being recognized and either return to hospital in circulatory collapse or die at home (Reich et al., 2003). An instant trial for early detection of such disorders was performed.

The present study demonstrates that, over a period of five months, POS allowed the early diagnosis of CHD in 45 neonates, including 12 neonates with major CHD .The list of diagnosed asymptomatic major CHD is interesting and also involves acyanotic lesions such as coarctation of the aorta and atrioventricular septal defect (Table 4).

One of the asymptomatic cyanotic CHD in our study was TA with ASD and VSD, oxygen saturation was below 90% several hour after birth and echo-cardiography done at the same time, although in TA there is some degree of cyanosis at birth , but her the cyanosis was not so evident probably due to the associated shunt (PDA) .

The normal course of postnatal oxygen saturation is well known (Toth et al., 2002): a healthy newborn at the age of two minutes has a mean arterial oxygen saturation of 73%, which rises to 95% within one hour. This process is individual and varies considerably, which explains the high rate of false positive POS test results in studies with screenings very soon after birth; (Valmari, 2007; Riede et al., 2009).

In our study population, 55/100 patients with a low saturation (positive POS) had a normal intracardiac anatomy. Pulmonary hypertension accounts for at least 10.9% of these false positive test results in our study. Early detection of persistent pulmonary hypertension in neonates is beneficial, including in the absence of CHD, since it can draw attention to an underlying problem like a sepsis.

Results in relation to other studies

Many previously published studies (Richmond et al., 2002; Hoke et al., 2002; (Koppel et al., 2003; Reich et al., 2003; Arlettaz et al., 2006; Bakr and Habib, 2005) attempted to assess the potential of pulse oximetry for screening for congenital heart disease study populations ranged from (2114 to 11281) to enable a confident estimate of sensitivity. But they have not included ascertainment of missed cases dying in the community that made unsupported claims of sensitivity, since (Wren et al., 2008) showed that an average of 5% of all babies with critical heart disease died undiagnosed in the community.

Depending on the cut-off criteria, the false positive rate of pulse oximetry screening varied between 0.009% and 5% in these studies. (Richmond et al., 2002) showed that the introduction of repeat pulse oximetry brought their false positive rate down from 5% to 1%.

In our study the sensitivity of POS for detection of CHD was 80%, and the rate of false positive result of POS was relatively high (2.6%), this high false result may be due to the screening of POS soon after birth and experience of doctor taking the measure, also our study sample is relatively small in comparison to other studies.

In Balu V et al shows poor sensitivity of POS (19%) in comparison with clinical examination which was much higher than POS and shows high false positive rate in comparison to our study.

In Balu V et al., study they thought that this low result may be due to the fact that only four patients in their study had critical CHD In addition, technical and human factors may also have contributed to the low sensitivity of pulse oximetry, Hence, repeated testing and adequate training of manpower is required before pulse oximetry can be recommended for clinical screening of CHD on a mass level.

In Mohamed A. et al study the sensitivity of POS was 84% which is relatively similar to our study and the rate of false positive of POS was 0.17% and this result is lower than our study because of large study sample in comparison to our study.

In Frank Th et al the sensitivity of POS was 77, 78% and positive predictive value was 25, 93% and false positive rate of POS was 0.10% which is relatively similar in comparison to our study

In de Wahl Granelli A et al the sensitivity of POS was 62% and false positive rate of POS in detection of major CHD was 0.17%.The difference in this result is attributed to large study sample in comparison to our study, and most of their sample screened after 24 hour of life which may lead to decrease the false positive rate in their study.

There is limited knowledge and cooperation from obstetrician to send for routine fetal echocardiography in our region, and also patient education therefore the percentage of CHD detected by prenatal ultrasound was 0% in our study.

In Wren et al the rate of antenatal detection of CHD was 20%. In Frank Th et al., there was a relatively high percentage of CHD detected by prenatal ultrasound (60%).

The limitation in our study were that we could not follow-up all cases after discharge for later diagnosis of congenital heart diseases because of insufficient data recordings and insufficient man power.

Another limitation in our study is that we didn't examine femoral pulses routinely; since half of the babies with duct dependent circulation detected at neonatal physical examination had poor or absent femoral pulses as a major alerting sign so the omission of palpation of femoral pulses is likely to reduce the detection of duct dependent circulation on clinical examination.

A strong points are relatively large number was studied, pre-and post ductal assessment of POS keeping POS results away from clinicians who performed physical examinations to reduce bias.

CONCLUSIONS

Our study showed that pulse oximetry screening of all well babies in maternity units is practically feasible with a minimum use of time, and that it significantly improves detection of life threatening congenital heart disease at an early stage. A significant number of newborns with critical congenital heart defects that have not been detected prenatally can be identified at an asymptomatic stage, before clinical deterioration occurs. This makes it possible to avoid cardiogenic shock in these patients before hospital discharge.

The low false positive rate, suggest that such screening will be cost effective. The ideal way of optimizing number of timely diagnoses is probably to have one pulse oximetry screening during the first 24 hours of life to prevent circulatory collapse in hospital of babies with duct dependent pulmonary circulation and to perform a second pulse oximetry screening at discharge.

Introduction of pulse oximetry screening is cost neutral in the immediate perspective, as each additional case that receives a timely diagnosis costs the same as the treatment of a child that is readmitted in circulatory collapse, but there are probably additional long term cost benefits from reduced neurological morbidity.

RECOMMENDATIONS

1. Pulse-oximetry screening should perform following 3-6 hours of age. If early discharge is planned, screening should occur as late as possible.
2. Conduct screening in a quiet area with to soothe and comfort the infant.
3. If possible, conduct screening while the infant is awake, quiet and calm.
4. Do not attempt to perform pulse oximetry on an infant while he or she is sleeping, crying or cold as oxygen saturations may be affected.
5. If using disposable pulse-oximetry probes, use one clean probe for each infant screened. If reusable probes are being used, clean probe as instructed by manufacturer prior to and following screening. Dirty probes may decrease the accuracy of a reading or transmit infection.
6. Perform pulse oximetry on the right hand and one foot after 24 hours of age. Measurements should be taken in parallel or one after another. If infant was born

prematurely, perform screening when medically appropriate.

7. Ensure that all readings are accurate by using pulse-oximetry equipment confidence indicators.
8. Perform POS according to the standard guideline or algorithm of POS in (figure1) and regard it as role in all pediatrics hospital in our region.
9. Follow-up all cases with positive POS after discharge from hospital are of great importance for later diagnosis of congenital heart diseases and provide sufficient data recordings.
10. Perform examination of femoral pulses routinely.

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