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Narayan, I.C.

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CHAPTER 6

Cost-effectiveness analysis of pulse oximetry screening for critical congenital heart defects in a setting with home births and short postnatal stay after in-hospital delivery

Ilona C. Narayen

Arjan B. te Pas

Nico A. Blom

M. Elske van den Akker-van Marle

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ABSTRACT

Background: Pulse oximetry (PO) screening can be used to screen newborns for critical congenital heart defects (CCHD). Analyses performed in hospital setting suggest that PO screening is cost-effective. We aimed to assess the costs and cost-effectiveness of PO screening in the Dutch perinatal care setting, with home births and early postnatal discharge, compared to a situation without PO screening..

Methods: Data from a prospective accuracy study with 23,959 infants in the Netherlands were combined with a time and motion study and supplemented data were used in this healthcare cost evaluation. Costs and effects of the situations with and without PO screening were compared for a cohort of 100,000 newborns.

Results: Mean screening time per newborn was 4.9 minutes per measurement and 3.8 minutes for informing parents. The additional costs of screening were in total €14.71 per screened newborn (€11.00 for personnel costs and €3.71 for equipment costs). Total additional costs of screening and referral were €1,670,000 per 100,000 infants. This resulted in an incremental cost-effectiveness ratio of €139,000 per additional newborn with CCHD detected with PO, when compared to a situation without PO screening.

Conclusions: PO screening in the Dutch care setting would be cost-effective if considerable savings in lifetime treatment and, or substantial gains in Quality Adjusted Life Years are obtained per infant timely diagnosed with PO screening. Additional studies on treatment costs, life expectancy and quality of life of children with CCHD are needed to conclude whether addition of PO screening is cost-effective in the Netherlands.

INTRODUCTION

Pulse oximetry (PO) screening to detect critical congenital heart defects (CCHD) in newborns has been studied widely in the past years and was proven to be accurate, safe, easy, and acceptable in settings with delivery and screening in hospital.¹⁻³ Cost-effectiveness analyses performed in studies from the United States and United Kingdom also suggest that the screening might be cost-effective in their setting.^{4,5}

Congenital heart defects are the most common congenital defect, affecting approximately 8 per 1,000 live births. One quarter of all congenital heart defects are critical and require surgery or catheter intervention in the first month of life.⁶ Timely diagnosis of these CCHD, before signs of cardiovascular collapse, is pivotal in reducing morbidity and mortality. Around 50-80% of CCHD can be detected with prenatal screening.^{7,8} Postnatal physical examination of remaining cases is hampered by the absence of clinical signs in the first days of life.⁹⁻¹¹ PO can be added to the regular screening program (prenatal ultrasound and postnatal examination) in order to reduce the cases with late diagnoses. It is known that a timely diagnosis of CCHD improves the chances of a favorable outcome with less mortality and morbidity.⁹

Although cost-effectiveness studies were performed in the United States and United Kingdom in settings with screening in hospital, costs might be different in settings with different perinatal care systems.^{4,5} For example, the Netherlands is unique with a high rate of home births (18%) and discharge within 5 hours after an uncomplicated vaginal delivery in hospital.^{12, 13} Screening in this setting requires performance of PO at home by community midwives, as well as a referral system for positive screenings. Recently, an accuracy study in the Dutch perinatal care was performed including 23,959 infants.¹⁴ We aimed to estimate the additional costs of PO screening in the Dutch perinatal care system, taking into account personnel time and equipment. The costs and cost effectiveness of a situation with PO screening were compared to the current setting, with effectiveness measured in terms of timely diagnosis (before death or signs of acute cardiovascular collapse).

METHODS

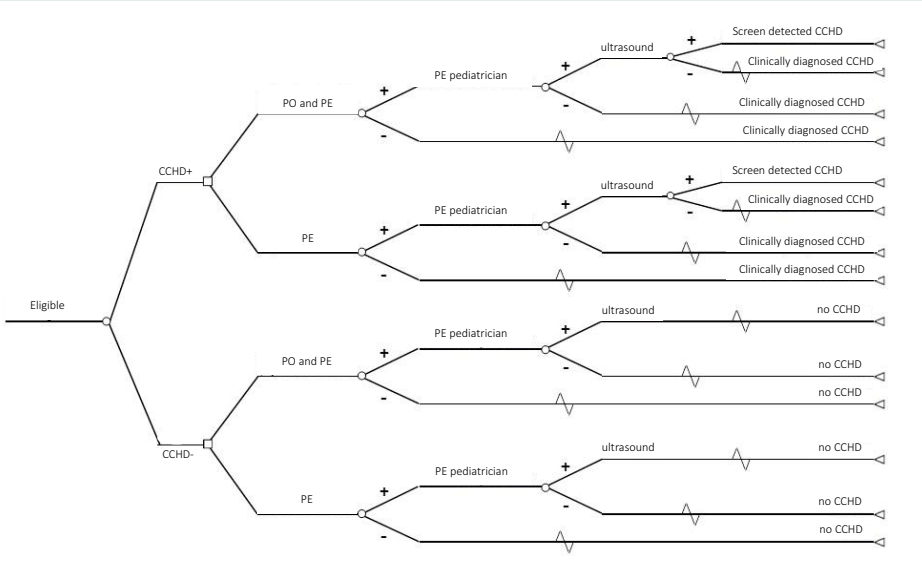
Screening strategies

The situation with PO screening as an adjunct to clinical examination was compared to usual care in which no PO screening was performed.

In the situation with PO screening, PO was added to physical examination of newborns and performed at home or in hospital at two moments: at least one hour after birth and on day two or three of the infant’s life. Infants with abnormal screenings were referred to the paediatrician for physical examination and a cardiac ultrasound was made in case of persistent abnormal oxygen saturations in the absence of a non-cardiac explanation.

In a situation without PO screening a physical examination is performed by the midwife or the obstetric nurse. If this examination has an abnormal result, referral to the paediatrician for examination including a cardiac ultrasound will take place. In Figure 1 both screening strategies are shown.

Figure 1. Schematic representation of screening pathways.



CCHD: critical congenital heart defect
PE: physical examination
PO: pulse oximetry

Clinical data

Clinical data for the situation with PO screening were obtained from the Pulse Oximetry Leiden Amsterdam Region (POLAR) study. The protocol and results of this study are published in another article.¹⁴ The study included 23,959 infants, six infants with CCHD were detected, five by abnormal PO results and one due to clinical symptoms, while five CCHD were missed (sensitivity 54.5%, specificity 99%). The false positive rate was 0.9%, but 61% of these infants had significant other pathology. Also, the percentage of referred neonates transported by an ambulance in a situation with PO screening were obtained from the POLAR study.

For the situation without PO, the number of physical examinations by midwives and obstetric nurses was assumed to be the same as in the situation with PO screening. Data on referrals were obtained from a review of patients' records before the introduction of PO. From all infants with CCHD that were not detected during antenatal anomaly scan, the records were reviewed in order to assess when the infants became symptomatic, if there was a timely diagnosis, and if postnatal physical examination revealed symptoms. The percentage of infants without CCHD with a false positive result in a situation with physical examination alone, was assumed to be 0.4%.³

The clinical parameters used in the model are summarised in Table 1.

Table 1. Model parameters for a situation with and without PO screening added to physical examination.

Parameter	Situation with PO screening		Situation without PO screening	
	Value	Source	Value	Source
<i>CCHD positive children</i>				
% screen positive by clinical examination and/or PO	54.5%	POLAR	25.8%	chart review
% transported by ambulance if screen positive	50.0%	POLAR	50.0%	POLAR*
% physical examination if screen positive	100%	POLAR	100%	expert opinion
% cardiac ultrasound if screen positive	100%	POLAR	100%	expert opinion
<i>CCHD negative children</i>				
% screen positive by PO	0.9%	POLAR	-	-
% screen positive by physical examination	0.4%	Ewer et al. (3)	0.4%	Ewer et al (3)
% transported by ambulance if screen positive	2.2%	POLAR	2.2%	POLAR*
% physical examination if screen positive	100%	POLAR	100%	expert opinion
% cardiac ultrasound if PO screen positive	18.1%	POLAR	-	-
% cardiac ultrasound if PE screen positive	100%	expert opinion	100%	expert opinion

*Assumed to be the same as in pulse oximetry and physical examination group. PO: pulse oximetry; POLAR: Pulse oximetry screening Amsterdam-Leiden region study.

Costs of screening and referral

The cost evaluation is performed from a healthcare perspective. All reported costs were converted to values for 2017, by means of the consumer price index.^{15, 16} As the cost of physical examination was assumed to be the same in the situation with and without PO, only the additional costs of PO were assessed.

A total of 28 community midwives recorded the time of 190 PO screenings. Also, the duration of the parent information talks during the antenatal visit and at the first screening moment were measured. We assumed that these time measurements were also representative for PO screenings performed by obstetric nurses. Personnel costs of the screening were obtained by multiplying the time duration of the screenings by the hourly gross salary costs of respectively midwives (€ 59, personal communication Royal Dutch Organization of Midwives (KNOV)) and obstetric nurses (€32).¹⁵

Cost of equipment was based on the purchase price of the used pulse oximeter devices and reusable sensor with wraps requested at the vendor (PM10N handheld pulse oximeters with reusable OxiMax sensors, Medtronic, Ireland, Dublin). We assumed a depreciation period of eight years for the pulse oximeter and 6 months for the sensors. Cost of annual maintenance were assumed to be 5% of the purchase price.¹⁵ The mean number of devices in midwife practices and hospitals was obtained from participating practices and hospitals in the study.¹⁴ This was multiplied by the number of midwife practices and hospitals in the Netherlands and divided by the total number of infants screened per year to obtain the costs of the device per infant screened.¹⁷⁻¹⁹

The percentage of neonates with a repeat PO screening was obtained from the POLAR study. Respectively 1.0% and 0.3% tests at the first and second moment of screening were repeated.

Referral costs included the cost of an outpatient visit to the paediatrician (€102), ambulance transport (€621), and costs of cardiac ultrasounds (€ 490) for the subgroup of neonates with persistent abnormal oxygen saturations without a non-cardiac explanation.^{15, 20}

Analysis

In the base case analysis, costs and effects of both the situation with and without PO screening are compared using the model parameters described above for a cohort of 100,000 neonates with a gestational age ≥ 35 weeks, that were not monitored with pre- and post-ductal SpO₂ in the first 24 hours of life and in whom no cardiac ultrasound was performed. The cost-effectiveness ratio was obtained by dividing the difference in costs in a situation with and without PO screening by the difference in number of timely diagnosed infants with CCHD.

Additionally, sensitivity analyses were performed to assess the impact of alternative assumptions for the model parameters on the incremental cost-effectiveness ratio.

In these sensitivity analyses the cost and effects of performing one measurement in the first hours after birth instead of two measurements was assessed. Performing only one measurement, leads to a lower sensitivity of 45.5%, a lower percentage of children without CCHD receiving a positive PO result (0.8%) and lower costs of screening. Furthermore, the effects and costs were assessed if a sensitivity of 70% was assumed for PO screening, which may also be likely for the Dutch situation.¹⁴

Also (univariate) sensitivity analyses on cost parameters were performed. In the base case analysis, a depreciation period of eight years for the pulse oximeter was assumed, this was changed in a five-year period in the sensitivity analysis, leading to higher material costs of screening (€4.32 per infant). The Dutch tariff for cardiac ultrasound in newborns is quite high compared to the costs assumed for the UK and the US,^{4,5} therefore also a sensitivity analysis with lower costs for cardiac ultrasound of €250 was performed.

Analyses were performed using Microsoft Excel (Microsoft, Seattle, WA) 2010 software.

RESULTS

Screening costs

A total of 190 PO screenings were timed by community midwives. The mean screening time was 4.9 minutes (SD 2.7 min, range 1.0-15.0 min). The mean parental information time was 3.8 minutes (SD 2.5 min, range 1.5-12.0 min). The two screening moments and parental information together amount to time costs of €11.00 per infant screened. Costs of pulse oximeter devices and the reusable sensor with wraps amount to €3.71 per infant, resulting in additional costs of PO screening of €14.71.

Effects and cost of screening with and without PO

In the situation without PO, 11 per 100,000 infants with CCHD were timely diagnosed. Adding PO, resulted in an additional number of 12 CCHD per 100,000 infants. In the situation with PO screening estimated cost of the addition of PO screening and referral amount to € 1,922,000 per 100,00 infants, of which the additional costs of PO screening account for €1,471,000 (Table 2). In the situation without PO screening costs of referral including ambulance transport, paediatrician visit and cardiac ultrasound were € 201,000 per 100,000 infants. Therefore, the additional cost of screening and referral in a situation with PO screening were €1,670,000 per 100,000 infants compared to a situation without PO screening.

Table 2. Cost of PO screening and referral in a situation with and without the addition of PO to PE screening, per 100,000 infants (2017 €).

Cost category	Situation with PO screening	Situation without PO screening
PO screening	1,471,000	0
Referral	452,000	252,000
- Ambulance transport	25,000	9,000
- Paediatrician	138,000	42,000
- Cardiac ultrasound	289,000	201,000
Total cost of screening and referral	1,923,000	252,000

PO: pulse oximetry; PE: physical examination.

The resulting incremental cost-effectiveness ratio, representing the additional cost per additional timely detected infant with CCHD, was € 139,000.

Sensitivity analysis

The sensitivity analyses in which base case values of the model parameters were changed, did not lead to important changes in the cost-effectiveness ratio, except for assuming a higher PO sensitivity, which resulted in a considerable lower cost-effectiveness ratio (Table 3).

Table 3. Cost and effects in a situation with and without the addition of PO to PE screening for different assumptions of the model parameters, per 100,000 infants (2017 €).

Sensitivity analysis	Situation with PO screening		Situation without PO screening		Cost effectiveness ratio
	Costs	Effects	Costs	Effects	Costs per additional timely detected infant with CCHD
Only PO measurement on day 1	1,299,000	19	252,000	11	128,000
Higher sensitivity PO (70%)	1,677,000	30	252,000	11	86,000
Shorter depreciation period pulse oximeter (5 years)	2,025,000	23	252,000	11	148,000
Lower costs cardiac ultrasound (€250)	1,627,000	23	252,000	11	136,000
<i>Base case</i>	<i>1,922,000</i>	<i>23</i>	<i>252,000</i>	<i>11</i>	<i>139,000</i>

CCHD: critical congenital heart defect; PE: physical examination; PO: pulse oximetry

DISCUSSION

The additional costs of PO screening are €14.71 per screened newborn. Total additional costs of screening and referral are €1,670,000 per 100,000 infants. This would implicate that the annual costs for implementing PO screening in the Netherlands would be €2.4million. With an estimate of 12 extra timely detected CCHDs per 100,000, this resulted in a cost-effectiveness ratio of €139,000 per timely diagnosis CCHD, when compared to the current management with antenatal anomaly scan and postnatal physical examination. A Willingness-To-Pay (WTP) threshold of €20,000 per gained Quality Adjusted Life Year (QALY) in the Netherlands for prevention indicates that PO screening in the Dutch care setting would be cost-effective if considerable savings in lifetime treatment and/or substantial gains in QALYs would be obtained per infant timely diagnosed with PO screening.²¹ It is known that the improved techniques of paediatric cardiac surgery and catheter interventions have considerably improved the outcome of children with CCHD in the last decades, with an improved life expectancy and quality of life.^{22, 23} However, exact and recent data on gained QALYs by timely diagnosis are lacking. The majority of infants with CCHD survive at least up to adulthood, and it is expected that the majority of them have normal life expectancy.²² Recent data have also shown that the short-term morbidity, mortality and length of hospital stay are reduced in case of timely diagnosis of CCHD.⁹ An analysis of the importance of timely diagnosis of CCHD, performed in the United States and based on a birth defect registry, stated that potentially preventable death occurred in 1.8% of infants with late detected CCHD, and that a late diagnosis was associated with more and longer hospital admissions, and higher inpatient costs.²⁴

PO screening performed in hospital setting in the US costed \$14.19 (2011) per screened newborn, which was less than the costs for metabolic (Guthrie test) screening and hearing screening in their setting.⁴ In a cost-effectiveness analysis of PO screening performed in the UK additional costs of PO screening were £6.24 (2009).⁵ In our screening protocol a part of the screenings were performed at home, with referral to hospital in case of a positive screening. Furthermore, we adopted a two-step screening strategy with PO measurements at two time points, causing higher personnel costs. These factors partly explain the higher costs of PO screening per newborn in our setting. Also costs of referral, especially of cardiac ultrasounds, were assumed to be higher for the Dutch situation, which together with the higher screening cost attribute to the less favourable cost-effectiveness ratio compared to the UK estimate of £24,000 per extra timely diagnosis of CCHD when compared to physical examination alone. As shown in the sensitivity analyses, the prenatal detection rate of CCHD has a large impact on the cost-effectiveness ratio; a high prenatal detection rate of CCHD in our implementation

study resulted in less CCHD detected postnatally, when compared to the other studies.¹⁴ This increases the costs per additional detected case as well.

A strength of this cost-effectiveness analysis is that it was based on data acquired by a large primary accuracy study, with an additional time and motion study to assess time duration of screening and informing parents.¹⁴ Although there was no concurrent control group with physical examination only, we were able to evaluate the accuracy by assessing a retrospective cohort from our own patient population from the period before PO screening was introduced. Although we did assess the additional costs per detected newborn with CCHD, we could not assess the costs per QALY, which is of high importance for policy makers. No other cost-effectiveness analysis in other countries could assess this however, due to lacking up-to-date long-term outcomes of children with CCHD. Another limitation is that we did not include treatment costs in this analysis, but studies have shown that the duration and amounts of hospital admissions is higher in case of late detection of CCHD.^{9,24}

An extra value of PO screening is the detection of other pathology, such as infections and respiratory morbidity.^{14, 25} Although these secondary targets were not included in cost-effectiveness analyses, it is likely that timely detection of these potentially life threatening pathologies can reduce morbidity and mortality in neonates.^{26,27}

CONCLUSION

This cost-effectiveness analysis assessed PO screening in the Dutch perinatal care setting with a high rate of home births and early postnatal discharge. We calculated that PO screening in the Dutch care setting would be cost-effective if considerable savings in lifetime treatment and/or substantial gains in QALYs would be obtained per infant timely diagnosed with PO screening. However, for this, additional studies on life expectancy, quality of life and treatment costs of children with CCHD are needed. The data we provided can be used by policy makers when considering implementation of PO screening.

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