Journal of Pediatric Sciences

Accuracy of Pulse Oximetry in Children with Congenital Heart Disease

Hamid Amoozgar, Reza Abbasi, Gholam Hossein Ajami, Mohammad Borzoee, Sirous Cheriki, Manuchehr Soltani

Journal of Pediatric Sciences; 2010; 2(2); e33

How to cite this article:

Amoozgar H., Abbasi R., Ajami G.H.Hussain N., Borzoee M., Cheriki S., Soltani M. Accuracy of Pulse Oximetry in Children with Congenital Heart Disease. Journal of Pediatric Sciences 2010;2(2):e33

ORIGINAL ARTICLE

Accuracy of Pulse Oximetry in Children with Congenital Heart Disease

Hamid Amoozgar, Reza Abbasi, Gholam Hossein Ajami, Mohammad Borzoee, Sirous Cheriki, Manuchehr Soltani

Abstract:
Background: Detection of arterial oxygen saturation in pediatric patients with congenital heart disease (CHD) can be helpful for their management.
Methods: We compared oxygen saturation and heart rate detected by pulse oximeter with the data of cardiac catheterization in order to determine the reliability and pitfalls of pulse oximetry (PO) in pediatric patients with CHD. 110 patients with different cyanotic and acyanotic CHD who were referred for right and left sided cardiac catheterization were enrolled in this study PO from left index finger and simultaneous oxygen saturations and pressures from cardiac catheterization were recorded.
Results: There was a statistically significant correlation (r= 0.68, p<0.0001) between measured oxygen saturation by PO and aortic oxygen saturation and between heart rate in elctrocardiography (ECG) and heart rate recorded by PO (r=0.94, p<0.0001) respectively. This study also showed that presence of cyanosis (p=0.01), digital clubbing (p=0.001), low oxygen saturation in supra-vena cava and right atrium (p=0.002, p= 0.01) can decrease accuracy of PO for detection of arterial oxygen saturation. High mean right atrial pressure can affect the accuracy of PO for detection of heart rate (p=0.034). PO had maximum sensitivity and specificity for detecting saturation of 88% and heart rate of 99 beat/min.
Conclusion: Pulse oximetry, within the above limits of accuracy, is a useful tool for estimation of arterial oxygen saturation and heart rate in children with CHD.

Key words: Congenital heart disease, Oxyhaemoglobin saturation, Pediatrics, pulse oximeter
Received: *06/04/2010; Accepted: 01/06/2010*

Introduction

There is no doubt that detection of arterial oxygen saturation by PO represents one of the greatest advances in patient monitoring during the last few decades. It has the unique advantage of continuously monitoring the saturation of hemoglobin, easily and noninvasively and providing a measure of cardio-respiratory function. By virtue of its ability to detect hypoxemia quickly, it has become the standard of care during anesthesia as well as in the recovery rooms, intensive care units, and all emergency situations [1].

Hamid Amoozgar, Reza Abbasi, Gholam Hossein Ajami, Mohammad Borzoee, Sirous Cheriki, Manuchehr Soltani

Division of Pediatric Cardiology, Shiraz University of Medical Sciences, Shiraz, Iran

Corresponding Author: ***Hamid Amoozgar, MD***

Department of Pediatrics, Nemazee Hospital, Shiraz, 7193711351; Iran.

Tele/fax: 98-711-6474298
e-mail: amozgah@sums.ac.ir

Pulse oximeter estimates percentage of oxygenated hemoglobin and detects hypoxemia [2,3]. Its function is based on two physical principles: firstly, the presence of pulsatile signal generated by arterial blood, which is relatively independent of non-pulsatile arterial blood, venous and capillary blood, and other tissues, and secondly by the fact that oxygenated hemoglobin and reduced hemoglobin have different absorption spectra [4]. The puls oximeter probe contains two

light-emitting diodes which emit light at the 660nm (red) and the 940 nm (near infrared) wave lengths, and a photo detector on the other side [5,6,7]. Pulse oximeters are calibrated empirically by using observations taken from healthy volunteers [8].

The probe may be clipped on fingertip, toe, bridge of nose, ear, forehead, palm or arm [9,10]. The accuracy of PO is affected by various conditions such as decreased blood perfusion (hypovolemia, shock and hypotension), intravenous dye injection such as methylen blue, badly positioned probe, tricuspid regurgitation and hemoglobin types other than oxygenated hemoglobin and reduced hemoglobin (carboxy hemoglobin, met-hemoglobin, hemoglobin S, etc), skin pigmentations, edematous limbs; and the site of probe and other determinant factors [11-15].The oximeters are very accurate when oxygen saturation ranges from 70% to 100% [16,17]. In congenital heart disease, PO along with the clinical examination, ECG and chest X-ray helps to evaluate the patient's condition.

This study was performed to assess the accuracy of PO in detection of arterial oxygen saturation and heart rate in pediatric patients with different cyanotic and acyanotic CHD and also clarify the possible causes of error for such measurement.

Materials and Methods:

Consecutive pediatric patients with cyanotic and acyanotic congenital heart disease who were referred for simultaneous right and left cardiac catheterization or intervention in Faghihi hospital, affiliated to Shiraz University of Medical Sciences, Shiraz, Iran were enrolled in this cross sectional study. The investigation protocol was approved by Medical Ethics Committee of Shiraz University of Medical Sciences. Informed consent was deemed unnecessary by the board because no intervention in any form was administered by the researchers. The following data were collected for each patient digital clubbing, capillary refilling, tricuspid regurgitation in echocardiography and type of CHD. Some patients received oxygen by mask. Oxygen saturation was measured by A-vax 1000 oximeter and pressures were measured in catheterization laboratory by Siemens 449 xi set angiography. Pulse oximeter (Model: Nellcor N-395) probe clipped on the left index finger and oxygen saturation and heart rate were recorded.

During cardiac catheterization the following parameters were recorded: oxygen saturation of aorta, pressure of aorta, right atrial pressure, right atrial oxygen saturation, supra-vena cava oxygen saturation, and heart rate which was recorded by ECG monitoring.

Linear regression was used to examine the relationship between aortic oxygen saturation and PO and detected heart rate in ECG and PO. Pearson product moment correlation was used to compare values obtained by the two methods. A receiver operating characteristic (ROC) curve was generated for specificity and sensitivity of PO in detection of heart rate and oxygen saturation and Bland-Altman diagrams was designed for the comparison between data obtained by PO and catheterization.

Results:

A total of, 110 patients were included in this study (48 males and 62 females) with a mean age of 6.88±6.82 years, mean weight of 20.45±16.12 Kg and mean height of 104.79±33.33 Cm. Types of CHD are shown in table 1.

Table 1. The underling congenital heart disease of patients.

Diagnosis	n	%
Tetralogy of fallot	22	20
Pulmonary atresia + VSD	4	3.7
VSD and pulmonary hypertension	22	20
ASD	7	6.3
PDA	23	20.9
Pulmonary stenosis	6	5.4
TGA	4	3.7
COA	4	3.7
Tricuspid atresia	2	1.8
Others Complex heart disease	16	14.5
Total	110	100

VSD: Ventricular septal defect, ASD, Atrial septal defect, PDA: patent ductus arteriosus, TGA: transposition of great artery, COA: coarctation of aorta

There was a statistically significant difference between PO with aortic oxygen saturation (p<0.0001). The Pearson Product moment correlation revealed statistically significant correlation between PO and aortic oxygen saturation. (r=0.68, p<0.0001). The linear regression analysis showed the following equation between PO and aortic oxygen saturation (figure 1): Aortic O2 saturation=0.786 *left hand SPO2 + 15.696 (r=0.68, p<0.0001)

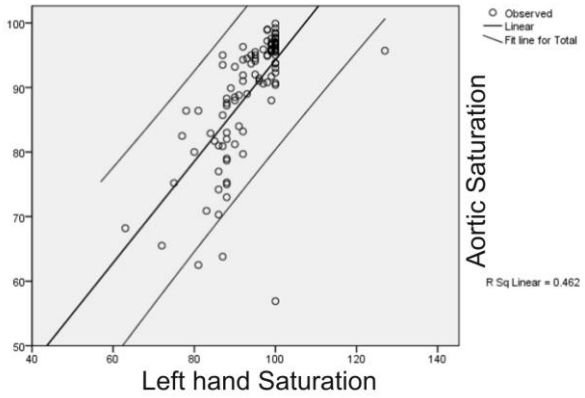

Figure 1. Scatter diagram with regression line and 95% confidence lines.

In addition, the Pearson product moment correlation revealed statistically significant relationship between heart rate detected by ECG and PO. (r=0.94, p<0.0001).

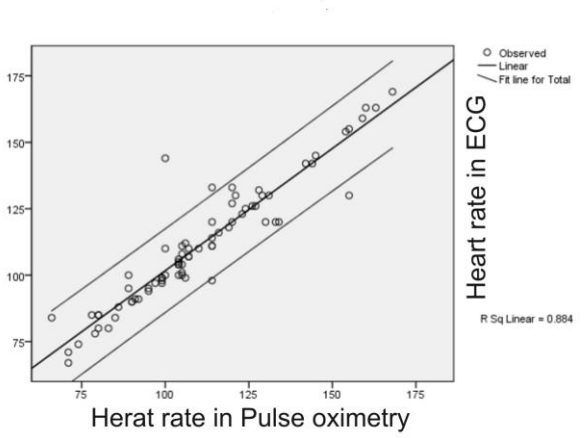

Figure 2. Scatter diagram with regression line and 95% confidence lines.

The following linear regression equation was shown between heart rate detected by ECG and PO (figure 2): ECG HR= 0.92 * PO HR + 9.756 (r=0.94, p<0.0001).

There was statistically significant difference in superior vena cava saturation and right atrial oxygen saturation between patients who had a difference more than 5% between aortic and left-hand oxygen saturation (superior vena cava oxygen saturation = 64.11 ± 10.415, 71.65 ± 12.440, p=0.002; right atrial O_2 saturation 73.20±9.699, 67.81±12.189, p=0.011).

In detection of heart rate by PO, there was statistically significant difference between mean right atrial pressure in those with error more than 5 /min in detection of heart rate by PO (3.33± 3.551, 6.90± 9.900, p=0.034).

In patients with clubbing of fingers and cyanosis statistically significant difference between aortic oxygen saturation and PO was observed (P<0.001, p<0.01) respectively. The effect of clubbing and cyanosis on HR was not statistically significant (p>0.05).

Tricuspid regurgitation, capillary refilling, oxygen intake, and sex had no statistically significant effect on the accuracy of PO for detection of oxygen saturation and heart rate (p>0.05).

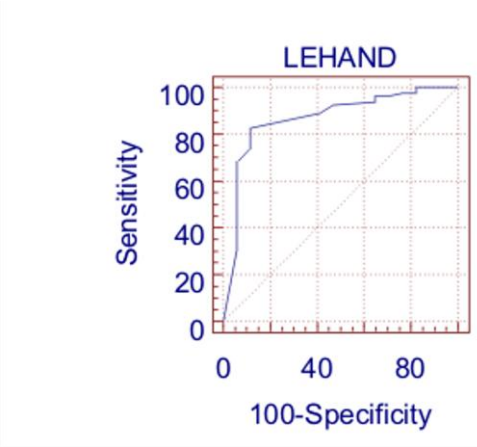

Figure 3. The interactive diagram revealing oxygen saturation detected by pulse oximeter, as derived from the ROC curve, for the detection of aortic oxygen saturation. LEHAND: oxygen saturation of left hand

A Roc curve generated for detection of saturation by PO showed the best accuracy at oxygen saturation of 88% with sensitivity of 82.9 and specificity of 88.2 , +LR=7.05,- LR=0.19; and for heart rate, the hot point was 99 beat/min with sensitivity of 100 and specificity of 83.3 , +LR=6,- LR=0.001 (figure 3,4).

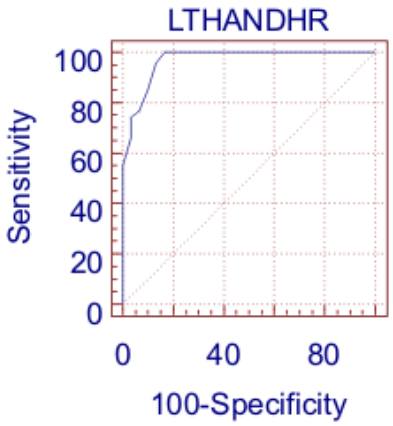

Figure 4. The interactive dot diagram revealing detected heart rate by pulse oximeter which derived from the ROC curve for the detection of electrocardiographic heart rate. LTHANDHR: heart rate detected by pulse oximetry of Left hand

Bland-Altman diagrams were generated for the comparison between PO and oximeter for measurement of saturation, and between PO and ECG for detection of heart rate (figure 5, 6).

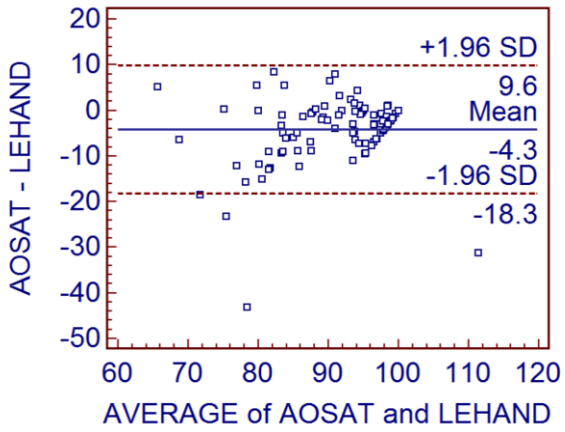

Figure 5. Bland-Altman diagrams for the comparison between aortic and left hand saturation. The dotted horizontal line indicates perfect agreement (difference of -4.3), the dotted lines indicate a clinically relevant difference of plus or minus 1.96. SD: standard deviation, AOSAT: Aortc saturation, LEHAND: oxygen saturation of left hand

Discussion:

Despite its known limitations, pulse oximetry remains a major part of care in all demanding clinical situations and its use for all patients under anesthesia must be mandated.

As with all monitors, one must be familiar with performance characteristics, advantages and limitations of PO [1].

In addition, when it is not possible to obtain arterial gas data, this method can be useful as a screening diagnostic procedure in patients with cardiovascular and other disease in which the clinical conditions do not always reflect the actual level of the arterial oxygen saturation. This study shows the accuracy of PO in detection of saturation and heart rate in pediatric patients with various CHD.

Detection of true oxygen saturation is an important step for better management of these patients and previous studies have revealed excellent correlation between arterial oxygen saturation and PO reading (R=0.95) [16,17].

In our study, a significant correlation between aortic oxygen saturation and PO reading was observed.

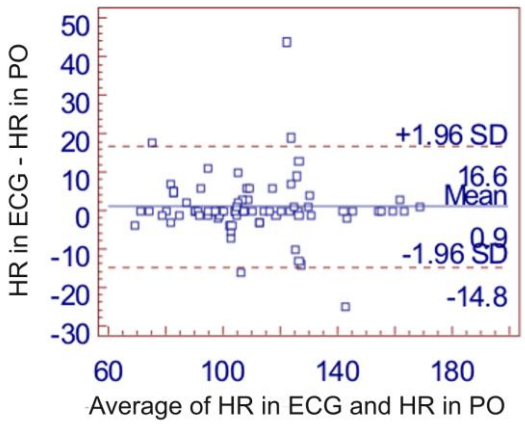

Figure 6. Bland-Altman diagrams for the comparison between aortic and left hand saturation. The dotted horizontal line indicates perfect agreement (difference of 0.9), the dotted lines indicate a clinically relevant difference of plus or minus 1.96. SD: standard deviation, HR: heart rate, ECG: Electrocardiography, PO: pulse oximetry

It can help to estimate true oxygen saturation by PO when detection of aortic oxygen saturation is not possible by invasive methods. Venous congestion, which may be caused by tricuspid regurgitation, high airway pressure and the Valsalva manoeuvre, may produce venous pulsations which can produce low readings [18]. In the present study, the influence of tricuspid regurgitation on the accuracy of PO was not documented, but low oxygen saturation in the right atrium and superior vena cava was a main cause for low accuracy ($p<0.001$).

Experimental data has shown that cyanosis and low level of oxygen saturation have a clinically significant effect on accuracy of pulse oximeters [19].

In this study, also PO had lower accuracy in cyanotic patients for detection of oxygen saturation. ($p<0.01$).

Filip and Karlien reported the influence of digital clubbing on detection of oxygen saturation in patients with cystic fibrosis [20]. We compared the PO accuracy in patients with and without clubbing. Our results confirmed that presence of digital clubbing decreases PO accuracy for detection of oxygen saturation ($p<0.001$). Past studies demonstrated that maximum accuracy of PO was at oxygen saturation of 70-100% [16,17]. In this study, the hot point of detection of saturation by PO was 88%.

Iyroboz et al. reported fine correlation between detected heart rate on ECG and by PO in adults [21]. We found a good correlation between heart rate on ECG and PO which can be helpful to estimate true heart rate. The best accuracy of PO to show true heart rate was in the heart rate of 99 beat/min.

In conclusion, pulse oximetry with mentioned limits of accuracy is useful in estimating arterial oxygen saturation and heart rate in pediatric patients with CHD.

REFERENCES

1-KamatV.Indian J Anesth. 2002;46:261-268.

2-Ralston AC, Webb RK, Run ciman WB. Anaesthesia. 1991;46: 202-206.

3-Kazuo IR, Yoichiro KA, Kazaburo AK. Anest Analg j.2003;96: 11-14.

4-Amal JU. Anest Analg j. 1999;3: 11-17.

5-Severinghaus JW, Honda Y.J Clin Monit. 1987;3: 135-138

6-Mary Jo. Crit Care Nurse. 2002;22: 69-74.

7-Tremper KK, Brakers J. Anesthesiology. 1989;70: 98-108.

8-Szaflarski NL, Cohen NH. Heart lung. 1989;18: 444-453.

9-Tersa mandal A, James M. Philipp J Intern Med. 1994;32: 261-264.

10-Tiltle M, Flynn MB. Dimens Crit Care Nurse. 1997;16: 88-95.

11-Feiner JR, Severing haus JW, Bickler PE. Anesth Analg. 2007;105:18-23.

12-Carlson KA, Jahr JS. Anesthesiol Rev. 1993;20:173-81.

13-Nickerson BG, Sorkision C, Tremper KK. Chest. 1988;93:515-517.

14-Clayton D, Webb RK, Ralstion AC, Duthie D. Anesthesia. 1991;46:260-265.

15-Scheller MS, Unger RJ, Kelner MJ. Anesthesiology. 1986;65:550-552.

16-Fanconi S, Doherty P, Edmords JF, Barker GA. J Pediatr. 1985;107:362-366.

17-Boxer, Pobert A, Gottes feld I, Singh S. Crit Care Med.1987;15:1062-1064.

18-Fearnley SJ. Update In Anaesthesia. 1995 ;5:1.

19-Schmitt HJ, Schuetz WH, Proeschel PA, Jaklin C. J Cardio thorac vasc Anesth. 1993;7: 61-65.

20-Filip V, Karlin V, Anne M. Journal Of Cystic Fibrosis. 2006;5: 125-128.

21-Iyriboz Y, Powers S, Morrow J, Ayers D. Br J Sports Med. 1991;25: 162-164.