CORRELATION BETWEEN MEASUREMENT OF ARTERIAL SATURATION BY PULSE OXIMETRY AND BY HEMOXYMETER IN CHILDREN WITH CONGENITAL HEART DISEASE

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Pulse oximetry is a noninvasive method of assessing hemoglobin arterial saturation, heart rate, and pulse amplitude which, for the past few years, has been used as an alternative to arterial blood gas analysis. There are few reports describing its use in the management of children with congenital heart disease, and this was the aim of our study. Sixty-one oximetry studies were done in 55 children who underwent cardiac catheterization. All were studied prospectively. There were 33 males and 22 females, with a mean age of 6.4 years (range, 0.5 to 29 years). During the invasive procedure, arterial saturation (SAT) and saturation by arterial blood gases (ABG) were measured. using the OSM 2 hemoxymeter and an ABL 300 instrument, respectively. Hemoglobin saturation (OXY) was simultaneously assessed non invasively by a Nellcor N-100 E pulse oximeter.

Statistical analysis of the data yielded an excellent correlation: OXY/SATr = 0.835; P< 0.001; ABG/SATr = 0.850; P< 0.001. In children with saturations lower than 85% (n = 16), the correlation was not significant (r = 0.419). The correlation for patients with oxygen saturation higher than 85% (n = 45) was significant: r = 0.669, P < 0.001. In children less than 4 years of age, the measurement was more accurate (n = 32, r = 0.850, P < 0.001) than in children older than 4 years (n = 29, r = 0.757, P < 0.001). There was a good correlation between OXY and SAT in children with a hematocrit less than 45% (n = 36, r = 0.855, P < 0.001) when compared with the correlation of those with a hematocrit higher than 45% (n = 25, r = 0.782, P < 0.001). We conclude that pulse oximetry is a reliable method for measuring hemoglobin saturation in children with congenital heart disease but should be used more selectively in children with low oxygen saturation.

The noninvasive measurement of oxygen saturation by pulse oximetry is attractive because it does not disturb the patient, is painless and easy to use, and does not require calibration. It can also be used for long-term monitoring as well as single measurements, the results can be read directly without the need for laboratory processing.

The method of pulse oximetry was initially described in 1975.1 In the 1980s pulse oximetry was shown to have a wide range of clinical applications that include patient care in the perioperative and postoperative periods, in patient transport, and care in patients suffering from respiratory failure.2-4 However, there are few reports on the use of this method in children with congenital heart disease.5,6 Therefore, the aim of this study was to evaluate the accuracy of pulse oximetry and to determine its reliability in detecting oxygen desaturation in pediatric patients with congenital heart disease.

Patients and Methods

Sixty-one measurements were performed in 55 patients (6 patients were studied twice). There were 22 girls and 33 boys with a median age of 4 years (range, 2 days to 29 years). All patients underwent cardiac catheterization as part of a diagnostic or therapeutic investigation. The mean heart rate (± SD) of the children was 110 ± 22 (71
to 190) beats per minute, and the mean hematocrit value (i: SD) was 43 i: 8.8% (26% to 64%).

The patients were supine throughout cardiac catheterization. The electrode of the pulse oximeter was attached to the right or left index finger of the patient. Hypotonic patients were excluded. Care was taken to prevent direct light from falling on the electrode and to keep the patient warm during the measurement. During cardiac catheterization, simultaneous measurements of oxygen saturation from a pulse oximeter was compared with oxygen saturation measured in vitro on obtained heparinized arterial blood samples. The age, weight, height, heart rate, and hematocrit were documented for each patient. Fetal hemoglobin concentration was not measured because most patients were over six months of age. The apparatus used for the study was a pulse oximeter (Nellcor model N-100, Drager, Lubeck). To determine the arterial saturation of the blood sample, a hemoxymeter (OSM 2, Radiometer, Copenhagen) was used. Blood gas analysis was performed with an ABL 300 instrument (Radiometer, Copenhagen).

**Principle of Pulse Oximeter**

Pulse oximetry uses the technique of absorption spectroscopy. The pulse oximeter estimates arterial hemoglobin saturation by measuring the light absorbency of pulsating vascular tissue at two wavelengths of 660 and 920 nm. The relationship between measured light absorbency and saturation was developed empirically and is built into the oximeter software.

**OSM 2 Hemoxymeter**

The OSM 2 hemoxymeter is a photometer that automatically measures hemoglobin saturation. This photometer uses two wavelengths of 505 and 600 nm. It differentiates between the wavelengths of oxyhemoglobin and deoxyhemoglobin and is the standard photometer for measuring oxygen saturation of blood samples taken in the catheter laboratory.

**Statistics**

Data were compared using linear regression analysis and calculation of correlation coefficients. The level of statistical significance was set at P < 0.05.

### Results

Simultaneous data were obtained from 61 studies in the 55 patients. The correlation between arterial saturation measured by pulse oximetry (OXY) with the hemoxymeter (SAT) and by the blood gas analyzer (ABG) showed the following results.

There was an excellent correlation between the arterial saturation measured by OXY when compared with the arterial saturation measured by SAT: OXY/SATn = 61, r = 0.835, P < 0.001 (Figure 1A). Furthermore, the arterial saturation measured by the arterial blood gas monitor correlated well with SAT: ABG/SATn = 61, r = 0.850, P < 0.001 (Figure 1B).
In children with saturations lower than 85% (n = 16), the correlation was not significant (r = 0.419) (Figure 2A). The correlation for patients with oxygen saturation higher than 85% (n = 45) was significant (r = 0.669, P < 0.001) (Figure 2B).

In children less than 4 years of age, the measurement was more accurate (n = 32, r = 0.850, P < 0.001) (Figure 3A) than in children older than 4 years (n = 29, r = 0.757, P < 0.001) (Figure 3B).

There was a better correlation between OXY and SAT in children with a hematocrit less than 45% (n = 36, r = 0.855, P < 0.001) (Figure 4A), when compared with the correlation of those with a hematocrit higher than 45% (n = 25, r = 0.782, P < 0.001) (Figure 4B).
ARTERIAL SATURATION (%)

Figure 4B. Relationship between the arterial saturation measured by pulse oximeter and by hemoxymeter for hematocrit levels > 45%.

Discussion

In the last ten years, pulse oximetry has been recognized to possess a wide range of clinical applications in the operating room, during patient transport, in postoperative care, and care in patients with respiratory failure. Few reports are available on the use of this method in children with congenital heart disease. An excellent correlation has been reported between oxygen saturation measured by pulse oximetry and by the standard techniques. Our data support reported findings, but many of these studies were concerned more with patients who were fully saturated.

Some authors suggested that the method has limitations in patients with low oxygen saturation. We were therefore interested to see if pulse oximetry would accurately reflect oxygen saturation in cyanosed patients with congenital heart disease.

Our patients were divided into two groups. One group had saturations over 85% while the other had saturations less than 85%; measurements of standard techniques were used. Our data confirm the data of others that low saturations are not measured as accurately as high saturations by pulse oximetry. Lower saturations yielded more dispersed data than did higher saturations. Pulse oximetry tends to overestimate arterial saturation at values below 85%. For clinical use these limitations are not as important when values either exceed 90% or are lower than 80%. If a patient with a value far less than 80% shows a high hematocrit, then the decision for further management, whether it is for a systemic-pulmonary shunt or for corrective surgery, is relatively straightforward.

We thought that it might be more difficult to measure saturation in children less than 4 years of age, but actually found that the opposite was true. This may be due to the fact that pulse detection is easier in younger children because they have less body mass. On the other hand, very small children are less likely to be cooperative and thus pose problems for pulse oximetry. In this study the patients were sedated when the measurements were made.

Because many cyanosed children tend to have high hematocrit values, we evaluated the effect of a high hematocrit on pulse oximetry measurements. There is a good correlation between the pulse oximeter measurement and the arterial saturation obtained by the hemoxymeter in children with a hematocrit less than 45%. However, this correlation was not as good in children with a hematocrit higher than 45%. This seems to indicate that a higher blood viscosity has a deleterious effect on the accuracy of pulse oximetry. Desaturation, high hematocrit, and an age over four years have cumulative negative effects on the accuracy of the pulse oximeter reading in cyanosed children who have high hematocrit levels.

The pulse oximeter detects changes in oxygen saturation quickly, accurately, and reliably. It is useful as an acute indicator of hypoxia. One of our patients with pulmonary stenosis experienced sudden hypoxia during cardiac catheterization, following occlusion of the right ventricular outflow tract with a balloon catheter. Pulse oximetry recorded both the fall in saturation during the occlusion and its return to normal when the occlusion was relieved by deflating the balloon.

To use pulse oximetry to its full potential, we must be aware of its limitations as well as its advantages. Because of the nature of the hemoglobin saturation dissociation curve, saturation measurements will not be sensitive to changes in PaO2 when the PaO2 is greater than 100 torr. Since the pulse oximeter uses two wavelengths of light, it cannot distinguish more than two hemoglobin species. Thus, carboxyhemoglobin and
methemoglobin will cause errors in oxygen saturation readings if present in large amounts. For example, smokers have high levels of carboxyhemoglobin and this might affect the results measured by pulse oximetry.

We conclude from our results that a noninvasive oxygen saturation measurement by pulse oximetry is accurate for saturations above 85%. Saturations below 85% are less reliably estimated by this method, though for clinical use the degree of accuracy is acceptable. We believe that pulse oximetry should be useful in the follow-up of patients seen in a pediatric cardiology clinic.

References