Journal of Bangladesh College of Physicians and Surgeons
Vol. 29, No. 3, July 2011

Pulse Oximetry: The Fifth Vital Sign of Neonates

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Summary:

When supplementation of oxygen is inappropriate there is chance of development of either hypoxia or hyperoxia. During oxygen therapy, oxygen level should be maintained within a target-able range through proper monitoring. Pulse oximetry is a useful convenient and reliable monitoring system. The principle of working of pulse oximeter is based on the fact that oxyhaemoglobin and deoxyhaemoglobin absorb light at the red end of the spectrum differently; Deoxyhaemoglobin absorbs more red than infrared and oxyhaemoglobin more infrared than red. The 'emitter' of the probe of pulse oximeter sends equal intensities of red and infrared light into the tissue. The 'sensor' detects the ratio of red to infrared that emerges. From this information the proportion of oxyhaemoglobin to deoxyhaemoglobin-that is, the percentage saturation of hemoglobin with oxygen is calculated and displayed to the monitor of the instrument. The main advantage of pulse oximeter is that it is non-invasive, less complex, does not require calibration, provides continuous measurement of hemoglobin-oxygen saturation (SpO_2), fast response time and high accuracy. Limitations of accuracy of pulse oximetry lie on poor perfusion, hypoxic events, hyperemia, severe anemia, dyshemoglobinemias, high oxygen partial pressures (P_aO_2), superficial pigments, black skin of infant, motion artifact, pressure on sensor, presence of abnormal dye, light and electrical interference. It is essential to remember the limitations of this instrument before going to pulse oximetry.

Key words: Pulse oximeter, neonate, vital signs, principals of working, limitations.

(J Bangladesh Coll Phys Surg 2011; 29: 158-162)

Introduction:

Oxygen is commonly used throughout the world in neonatology[1]. There is chance of development of either hypoxia or hyperoxia if supplementation of oxygen is inappropriate. Hypoxia may lead to pulmonary vasoconstriction, pulmonary hypertension, neurological and other organ damage[2]. This condition may be associated with lethargy, cyanosis, hypothermia, bradycardia, metabolic acidosis or unresponsiveness to therapy[3]. Hyperoxia on the other hand produces complex physical and physiological stress[4]. It produces free radical mediated cellular damage. A number of diseases in the newborn may occur as consequences of oxygen free radicals e.g. retinopathy of prematurity, bronchopulmonary dysplasia, necrotizing enterocolitis and patent ductus arteriosus etc[3].

A good monitoring system of oxygen level is essential during its supplementation. The primary aim of monitoring of oxygen is to reduce hypoxic and hyperoxic episodes and to decrease the variability in an infant's oxygen levels through proper monitoring[5].

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Received: 30 Nov. 2010 **Accepted:** 20 June 2011

There are many monitoring systems of oxygen saturation in newborn infants. In a country like ours, where facilities are constrained, a convenient, user friendly but reliable monitoring system is prioritized. Historically, the pulse and respiratory rate were the initial vital signs because their determination did not rely on any instrument. Body temperature and blood pressure recording were added as next vital parameters with simple instruments in the year of 1850 and 1900 respectively. The pulse oximeter was introduced in the early 1980_s as the 5th vital sign for accurate, precise, noninvasive measurement of arterial hemoglobin oxygen saturation. Information derived from all five reflects crucial physiological function of neonate[6].

Pulse oximeter is a good and convenient instrument that can be used even in rural areas to monitor oxygen saturation. Knowledge regarding fundamental aspects of pulse oximeter and monitoring of oxygen saturation by this instrument is prerequisite for taking reading of oxygen saturation accurately by this instrument. Scarcity of working knowledge among our physicians regarding pulse oximetry is a problem. Many studies on oxygen monitoring through pulse oximeter are conducted in different parts of the globe. But work in neonatology on our country is very limited. The review is written to orient our clinicians particularly pediatricians, regarding

some fundamental aspects of pulse oximetry so that oxygen mediated problems could be minimized.

Oxygen status in neonate:

Before going to discuss pulse oximetry, it is wise to know some basic concept of oxygen therapy. Different researchers studied oxygen levels in neonates in different parts of the world. At 5 minutes of postnatal age, the observed median SpO_2 value was 87% for infants delivered vaginally and lower value for those delivered through cesarean section. The median SpO_2 did not reach 90% until 8 minutes of age in either group[7]. Another group of researchers observed median SpO_2 at 1 minute was 63% with a gradual rise of 90% at 5 minutes[8]. The best range for SpO_2 was observed as 91% -96%[9].

Saturation within the range 85-95% largely exclude hyperoxia in preterm infants <29 weeks gestation but permit PaO_2 values far lower than those recommended in traditional guidelines[10]. Oxygen level (SpO_2) observed in Bangladeshi neonates were 95%, 94% and 92% respectively among 1st, 2nd, 3rd and 4th week of postnatal age. The normal SpO_2 value ranged from 87% to 94% in terms of normal PaO_2 (50-80 mmHg) value[11].

Principles of oxygen therapy:

In neonate the goals of oxygen therapy are (i) to maintain adequate partial pressure of oxygen in arterial blood (PaO_2), (ii) to minimize the work of breathing and (iii) to minimize the cardiac work[12].Oxygen should be administered only when indicated, given in the lowest ambient concentration and should be stopped as soon as its use is considered unnecessary[3]. A PaO_2 values of <40 mmHg and >80 mmHg is regarded as 'low' and 'high' PaO_2 values by neonatologists[13]. A PaO_2 value of 40-80 mmHg corresponds to SpO_2 values of 85-93% in majority of cases[12]. A PaO_2 of 41 mmHg may be enough to saturate 90% of hemoglobin in very low birth weight infants[14].

Strict management of oxygen therapy to minimize episodes of hyperoxia and hypoxia was associated with decreased incidences of retinopathy of prematurity (ROP) over a period of 5 years[15].In special conditions like preterm VLBW, chronic lung disease (CLD), bronchopulmonary dysplasia (BPD) oxygen therapy should be individulaised[5,12,15,16]. Generally SpO_2 is maintained at 85% -95% (85% - 92% if <29 weeks gestation) range[17]. In acute condition, the arterial oxygen saturation should be maintained between 90-95% and between 85-90% in chronic situations[3]. Oxygen can be administered through nasal prongs, nasal catheter, nasopharyngeal catheter, oxygen hood (head box), face mask and holding oxygen source close to the infant's face[18]. Oxygen may also be given through endotracheal tube connecting with self-inflating bag, continuous positive airway pressure (CPAP) or ventilator system[19].

Monitoring of oxygen:

It is useful to monitor ambient oxygen concentration by 'oxygen analyzer' in order to protect infant against oxygen toxicity. It helps in regulating the flow rate of oxygen so that desired concentration of oxygen can be delivered[3]. However, monitoring of oxygen directly on neonate is very important.

The objectives of oxygen monitoring is to prevent oxygen mediated complications notably reduction injury to lungs, immature retina and other tissues. In the long run the purpose of oxygen monitoring is to detect degree of hypoxia, which is likely to cause acidosis or tissue damage and hyperoxia, which may causes predominantly retinopathy of prematurity[20].

Monitoring systems:

Cyanosis may be a guide for oxygen status. But it is very much subjective and evident only when saturation is markedly low. Again, polycythemic patient may appear cyanosed despite adequate arterial oxygen tension[21]. The important monitoring systems of oxygen therapy are as follows:

1. Arterial blood gas (ABG) analysis:

Blood gas analysis provides information essential for assessment, therapeutic decision-making and prognostication of patient. The normal values of arterial blood gases are very dependent on many factors including gestational age and postnatal age of infants[22]. However, a value of 50-80 mmHg is considered as target range of partial pressure of oxygen of arterial blood (PaO_2) for newborn infants[17]. Blood sampling via umbilical artery or peripherally is preferred route. Radial or posterior tibial arteries are commonly used. Complications related to radial artery puncture include hematoma formation, arterial spasm, thrombosis, embolism, infection and inaccuracy of results[19]**.** Though such arterial blood gas analysis is considered to be the gold standard for accuracy, it provides intermittent

oxygen monitoring, is invasive, can lead to significant blood loss and erroneous results may be found if sampling is improper[23].

2. Continuous blood gas monitoring:

Continuous blood gas monitoring through an indwelling catheter has been advocated to provide rapid, real-time data and reduce the volume of blood required for repeated blood gas measurements. Recent technology has been utilized for fiber optic systems optical sensors inserted into vascular catheters already in place. Correlation with measured PaO_2 values is good but bias and precision of measurements deteriorate for PaO_2 values above 70 mm Hg[17].

3. Capillary blood gas determination:

This technique requires extensive warming of the extremity, free-flowing puncture, and strictly anaerobic condition. Under such conditions, capillary sample may be useful for determination of pH and PcO_2. Proper collection techniques are often difficult to guarantee in technical setting; however, capillary sample should not be used for determination of PaO_2[17].

4. Transcutaneous oxygen (t_cPo_2) monitoring:

Here, partial pressure of oxygen is measured from skin surface by an electrochemical sensor[19]. The sensor is affixed over the chest or upper abdomen[3]. Oxygen diffuses through a membrane into the electrode, when it is reduced, setting up an electric current[22]. The skin surface is heated to 43.5° to 44°c to maximize skin surface blood flow[17]. The electrical current is related to PaO_2 and is displayed as transcutaneous Po_2 ($tcPo_2$)[22]. This value is reliable and comparable to simultaneous PaO_2. Sensor site is to be changed every 2 hourly to avoid skin burn[3].

5. Pulse-oximetry (SpO_2):

It is very difficult to guess the state of a patient's arterial oxygenation subjectively. Introduction of pulse-oximetry in the early eighties allows reasonably accurate objective assessment of P_aO_2[24]. Its availability will help to pick up any significant change in oxygen saturation in newborn infants[25].Study has shown that using pulse-oximetry as a routine 'fifth vital sign' resulted in important changes in the treatment of a proportion of patient[26].Control of oxygenation is achieved by maintaining saturation within a target range, usually by setting alarm limits[10].

(i)Principles of working:

Oximeter makes use of the fact that oxyhaemoglobin and deoxyhaemoglobin absorb light at the red end of the spectrum differently; Deoxyhaemoglobin absorbs more red than infrared and oxyhaemoglobin more infrared than red[27]. The wavelengths of red and infrared light are 660 nm and 940 nm respectively (Fig-1)[28]. The oximeter probe consists of a 'light emitter' and a 'light sensor', which are aligned on opposite sides of a narrow part of body, such as palm or forefoot. The 'emitter' sends equal intensities of red and infrared light into the tissue. The 'sensor' detects the ratio of red to infrared that emerges. From this information the proportion of oxyhaemoglobin to deoxyhaemoglobin-that is, the percentage saturation of haemoglobin with oxygen is calculated and displayed[27].As oximeter measures the saturation of arterial blood rather than capillary or venous blood, the instrument is programmed to look only at pulsatile increases in oxyhaemoglobin concentration-hence the term 'pulse' oximetry[27]. The pulsatile signals are due to variability of arterial cross-sectional area and change in axis of erythrocytes with each cardiac cycle[24]. When light is passed through tissue some of the light is absorbed by each constituent of the tissue, but the only variable light absorption is by arterial blood (Fig-2)[29].

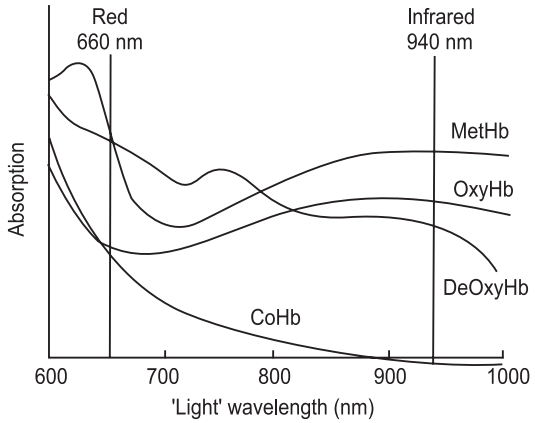

Fig.-1: *Absorption spactra of normal adult haemoglobin in saturated (OXyHb) and desaturated (DeXoyHb) states, carboxyhaemoglobin (COHb)(, and methaemoglobin (MetHb)*

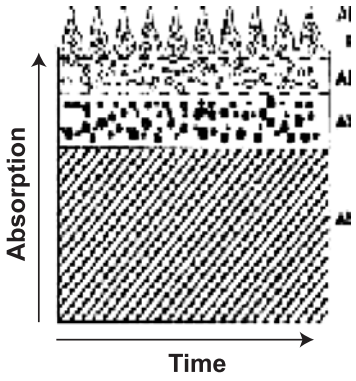

Fig-2: *Source of light absorption during pulse oximetry.*

- absorption by pulse added volume of arterial blood.
- absorption by arterial blood.
- absorption by venous blood
- absorption by tissue.

Conclusion

Oxygen therapy should be judicious. Inappropriate supplementation of oxygen may not correct hypoxia or may lead to hyperoxia. Both the conditions are injurious to neonatal health. During oxygen therapy, SpO_2 value and more precisely the PaO_2 value on neonate should be maintained within a target range. There are some monitoring systems of oxygen status in neonate. Pulse oximeter is a convenient-reliable instrument for recording oxygen saturation. Control of oxygenation may be achieved within a target-able range with this instrument. During pulse oximetry, its limitations and pitfalls should be remembered. Time-to-time PaO_2 monitoring through arterial blood gas analysis is also important.

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