MONITORING OF OXYGEN IN NEONATE: AN IMPORTANT ISSUE

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Summary

Oxygen is commonly used in neonatal unit. Injudicious use of oxygen may lead to development of hypoxemia or hyperoxemia which is injurious to health. The goals of oxygen therapy are to maintain adequate partial pressure of oxygen in arterial blood, to minimize the cardiac work and to reduce the work of breathing. The normal SpO_2 value in terms of normal PaO_2 (50-80 mmHg) value in Bangladeshi neonates ranges from 87% to 94%. Supplementation of oxygen needs proper monitoring. There are many monitoring systems of oxygen saturation in newborn infants. But pulse oxymetry is regarded as the 'fifth vital sign' due to its various advantages in monitoring oxygen status in neonate. Consideration of pitfalls of using pulse oximeter is essential for recording oxygen saturation accurately.

Key words : Oxygen saturation; monitoring; neonate

Introduction

Oxygen is commonly used in neonatal unit throughout the world[1]. Injudicious use of oxygen may not maintain appropriate oxygen status of neonate- rather may lead to development of hypoxemia or hyperoxemia. 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 through lipid peroxidation, inactivation of enzymes, damage of DNA and structural protein. A number of diseases e.g. retinopathy of prematurity, bronchopulmonary dysplasia, necrotizing enterocolitis and patent ductus arteriosus etc in the newborn may occur as consequences of oxygen free radicals[3].

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Supplementation of oxygen needs proper monitoring. 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[5]. There are many monitoring systems of oxygen saturation in newborn infants. Many studies on oxygen therapy are conducted in different parts of the globe. But works in neonatology in our country are very lacking. The review is written to orient our physicians regarding some important fundamental aspects of oxygen therapy in neonates so that oxygen mediated untoward effects could be minimized.

Oxygen levels in newborn infants

Many workers studied oxygen levels in neonates in different parts of the world. At 5 minutes of age of neonates, the observed median SpO_2 values were 87% for infants delivered vaginally and 81% for those delivered through cesarean section. The median SpO_2 did not reach 90% until 8 minutes of age in either group[6]. Another group of researchers observed median SpO_2 at 1 minute was 63%. Gradual rise in SpO_2 with time, with a median SpO_2 at 5 minutes of 90% was observed[7]. The best fixed lower and upper limits for SpO_2 was seen as 91% and 96% by other workers[8].

The 95% CI of PaO_2 for the SpO_2 range 85-95% was 3.8 to 8.9 kPa in neonates with <32 weeks gestational age. The mean PaO_2 at a saturation of 85% was 5.3 kPa and at a saturation of 95% it was 7.2 kPa. The workers concluded that saturations 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[9]. Oxygen level (SpO_2) observed in Bangladeshi neonates were 95% in 1st and 2nd weeks, 94% in 3rd and 92% in 4th week of postnatal age. The normal SpO_2 value in terms of normal PaO_2 (50-80 mmHg) value observed in those neonates ranged from 87% to 94% [10].

Goal and principles of oxygen therapy

The goals of oxygen therapy are (i) to maintain adequate partial pressure of oxygen in arterial blood (PaO_2), (ii) to minimize the cardiac work and (iii) to minimize the work of breathing[11]. Principle of oxygen therapy is to provide oxygen in such quantities that it will maintain appropriate oxygen level in blood. Oxygen should be administered only when indicated, given in the lowest required 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[12]. A PaO_2 value of 40-80 mmHg corresponds to SpO_2 values of 85-93% in majority of cases[12]. Maintenance of partial pressure of oxygen within such range minimizes the chances of blindness caused by retinopathy[11]. In very low birth weight newborns, when treating with oxygen, a PaO_2 of 41 mmHg may be enough to saturate 90% of hemoglobin at a physiological pH[13].

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 from 12.5% in 1997 to 2.5% in 2001[14]. Full term neonates with diaphragmatic hernia or persistent pulmonary hypertension may require more PaO_2 values[11]. The objective of oxygen therapy in infant with bronchopulmonary dysplesia is to avoid use of high concentration of inspired oxygen with maintaining adequate oxygenation[15]. Incidence of chronic lung disease (CLD) and ROP was decreased when lower concentrated oxygen was administered[5]. Generally SpO_2 is maintained at 85% to 95% (85% - 92% if <29 weeks gestation) range[16].

Indications and methods of oxygen therapy

The main indications of oxygen therapy are[3]:
(i) *Perinatal asphyxia*. (ii) *Cyanosis* (excluding congenital cyanotic heart disease without cardiac failure and methemoglobinemia). (iii)*Respiratory distress*. Therapy is indicated if respiratory distress is worsening or if any feature of hypoxia is evident or if PaO_2 is <40 mmHg or SpO_2 <85% (iv) *Hypothermia* (v) *Recurrent apneic spell. (vi) Pneumothorax or pneumomediastinum.*
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[17]. Oxygen may also be given through *endotracheal tube* connecting with self-inflating bag, continuous positive airway pressure (CPAP) or ventilator system[18].

Monitoring of oxygen

It is useful to monitor ambient oxygen concentration by 'oxygen analyzer'. It helps in regulating the flow rate of oxygen so that desired concentration of oxygen can be delivered[3]. Monitoring of oxygen directly on neonate is definitely very important and should be initiated as soon as possible.

Objectives of oxygen monitoring

The objectives of oxygen monitoring is to prevent oxygen mediated complications notably reduction of 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[19].

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, plethoric and polycythemic patient may appear cyanosed despite adequate arterial oxygen tension[20]. The important monitoring systems of oxygen therapy are as follows:

1. Arterial blood gas (ABG) analysis

Blood gas analysis provides information essential to assessment, therapeutic decision-making and prognostication of patient.*Usual values: The normal values of arterial blood gases are very dependent on many factors including gestational age and postnatal age of infants[11].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[16].*Sampling sites: This require arterial puncture or and indwelling arterial catheter. Access via the umbilical artery or peripherally is now prefered route[18]. Radial or posterior tibial arteries are commonly used.[21].*Complications: Complications related to radial artery puncture include hematoma formation, arterial spasm, thrombosis, embolism, infection and inaccuracy of results[18].*Merits and demerits: Direct blood gas sampling from arterial lines to measure partial pressure of oxygen in arterial blood (PaO_2) is considered to be the gold standard for accuracy. This method, however, only provides intermittent oxygen monitoring. It is invasive, can lead to significant blood loss and erroneous results may be found if sampling is improper. New micro method of arterial blood gas sampling may be preferable to commonly used 'drip technique' specially for low birth weight infants in whom minimization of blood loss is essential[22].

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. Reported correlation with measured PaO_2 values is good in some studies but bias and precision of measurements deteriorate for PaO_2 values above 70 mm Hg is observed. The sensor also can not be threaded into some brand of umbilical catheters smaller than 5 Fr.[16].

3. Capillary blood gas determination

This technique requires extensive worming 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[16].

4. 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[23]. Its availability will help to pick up any significant change in oxygen saturation in newborn infants[24].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[25].Control of oxygenation is achieved by maintaining saturation within a target range, usually by setting alarm limits[9].

(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[26]. The wavelengths of red and infrared light are 660 nm and 940 nm respectively[27]. 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[26]. 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[26]. The pulsatile signals are due to variability of arterial cross-sectional area and change in axis of erythrocytes with each cardiac cycle[23]. 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[28].

(ii) Advantages and disadvantage of pulse-oximetry

It is non-invasive, less complex, does not require calibration and provides continuous measurement of hemoglobin-oxygen saturation (Spo_2)[16]. Response time of this instrument is fast[29] and accuracy is high (±3%)[16]. The main disadvantage of pulse oximeter lies on its limitations. The '*safe limitation*' is that when the machine is not indicating the correct value of SpO_2 and the user is warned that the value may be incorrect. '*Dangerous limitation'* is that when the machine appears to operating satisfactorily but actually operating wrong value of SpO_2[23].Complications associated with use of pulse oximetry have been reported. These include pressure erosion, skin necrosis, digital sensory loss and even burn[30].

(iii) Pitfalls and limitations

Following limitations of pulse oximeter is to remember during its applications:

Dyshaemoglobinemias*-Accuracy of pulse oximetry is excellent when oxygen saturation ranges from 70% to 100%, provided haemoblobin present in blood are reduced haemoglobin or oxygeneted haemoglobin.[29].Poor purfusion*-Adequate arterial pulsation is needed to distinguish the light absorbed by venous blood and tissue. Reading may be unreliable or unavailable if there is loss of diminution of peripheral pulse[29]. Pulse oximeter works properly if pulse pressure is >20 mmHg or systolic BP>30 mmHg[21].**Motion artifact*-Motion of sensor relative to skin can cause an artifact that the pulse-oximeter is unable to differentiate arterial pulsation[29]. Now a day's various methods have been developed to reject motion artifact[27]. Sensor may perform poorly if there is excessive movement of concerned part of neonate[31] **Pressure on the sensor*-Pressure on sensor may result in inaccurate SpO_2 readings without affecting pulse rate determination[29]. **Hyperemia;* In this condition capillary and venous blood becomes pulsatile, resulting decrease in accuracy[29].**Abnormal dye*-Pigments like methylen blue, severe hyperbilirubinaemia may interfere readings of pulse-oximetry[32].**High oxygen partial pressures*: At high saturations, small changes in saturation are associated with relatively large changes in PaO_2.Thus the pulse oximeter has a limited ability to distinguish high but safe levels of arterial oxygen from excess oxygenation, which may be harmful as in premature newborns[29].**Hypoxic events*: Delay response in hypoxic events are related to location of sensor. Desaturation is detected earlier when the sensor is placed more centrally. Lag time increases with poor perfusion, venous obstruction, peripheral vasoconstriction and hypothermia[29].**Electrical interference*: Electrical interference from an electro-surgical unit can cause the oximeter to give an incorrect pulse count or to falsely register decrease in oxygen saturation[29].**Light:*A photo diode used as light detector in pulse oximeter sensor produces current when any light hits it. It can not tell whether the light is coming from the red or infrared light emitting diodes (LED) of the pulse oximeter sensor or from room bright light[33].**Other factors:* Severe anemia, superficial pigments, black colour of infant is a problem in readings of pulse-oximetry[32].

5. Transcutaneous oxygen (t_cPo_2) monitoring

Here, partial pressure of oxygen is measured from skin surface by an electrochemical sensor[18]. 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[21]. The skin surface is heated to 43.5'c to 44°c to maximize skin surface blood flow[16]. The electrical current is related to partial pressure of

oxygen (Pao_2) and is displayed as transcutaneous Po_2 ($tcPo_2$)[21]. This value is quite reliable and comparable to simultaneous PaO_2, which should be crosschecked every 4 to 6 hours. Sensor site is to be changed every 2 hourly due to risk of skin burn[3]. Correlation with PaO_2 is poor in neonate with circulatory insuffiency and if operated at low sensor temperature[16]. A discrepancy of >20 % in $tcpo_2$ placing sensor over right upper chest and another sensor over left lower abdomen is indicative of significant right to left shunt[3].

Conclusion

Oxygen supplementation is a common practice in neonatal unit. Inappropriate supplementation of oxygen may be associated with hypoxia or hyperoxia. Both the conditions are injurious to newborn babies. So during oxygen therapy judicious administration of oxygen is essential- 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. Control of oxygenation may be conveniently achieved within a targetable range with monitoring system like pulse oximetry. It is necessary to remember limitations of pulse oximeter during its use and time-to-time PaO_2 monitoring is also important.

Disclosore

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