

Pulse Oximeter

Pulse oximeter is a commonly used device, in neonatal intensive care units for monitoring oxygenation in newborn babies. It is difficult to imagine the era which ended 30 years ago, when the only practical assessment of a patient's oxygenation was the presence or absence of cyanosis. Until recently, measurement of arterial blood oxygen saturation required the direct sampling of arterial blood, which though not difficult was invasive and potentially risky. Furthermore arterial blood gas sampling provides only intermittent monitoring and remains relatively expensive. Fortunately, a major advancement in this field was the development of pulse-oximetry to determine percent saturation of haemoglobin with oxygen. Today pulse-oximetry provides a simple, non-invasive, portable and inexpensive method to continuously monitor oxygen saturation and heart rate with good accuracy.

The core physical principles, based on which pulse oximetry works are

- 1) The presence of a pulsatile signal generated by the arterial blood flow and
- 2) The difference the absorption spectra of oxyhemoglobin (HbO) and reduced hemoglobin (HbH)

As we are interested in whether oxygen is attached to haemoglobin or not, the relevant solutes are oxyhaemoglobin (HbO) and reduced haemoglobin (HbH). The difference in peak absorption characteristics of these two forms of hemoglobin, at wavelengths of 660 nm (red) and 940 nm (infrared), are used in pulse-oximetry. Reduced hemoglobin absorbs more red than infrared light and oxygenated haemoglobin absorbs more infrared than red. Further, only the pulsatile change in light transmission through living tissue is measured to calculate arterial saturation with the understanding that such a change in light transmission would solely be due to change in intervening blood volume. Thus absorption of light by venous blood, skin pigments, tissue and bone is automatically eliminated from consideration.

Practical working of pulse-oximeter

Probe of pulse oximeter consists of two diodes which emit equal intensities of red and infrared light in sequence into pulsatile tissue bed. Variable amount of these lights are absorbed by oxygenated and reduced haemoglobin. A photodetector placed on the opposite side senses the ratio of red and infrared light based on which the proportion of oxygenated and reduced haemoglobin is estimated by an in built micro-processor and digitally displayed.

The final saturation of hemoglobin is derived by measuring the ratio of light absorbed at the red wavelength i.e. 660nm to that absorbed at the infrared wavelength i.e. 940nm and this will correlate with O₂ saturation.

Correlation with Pa O₂

The PaO₂ at any given saturation is a function of the “oxyhaemoglobin dissociation curve” which is sigmoid in shape. As this curve reaches flat upper end, further increase in PaO₂ causes little change in saturation. If pulse oximeter shows high saturation (around 100%), one never knows how high the actual PaO₂ might be.

Limitations

The pulse oximetry is often described as a “fair weather friend”. It is less accurate in the following situations: Motion, Low perfusion, Local hypoxemia, Venous pulsations and congestion, other hemoglobins, Light interference, Bilirubin, intravascular dyes, nail polish, Electromagnetic waves in the vicinity. But the modern pulse oximeters have found methods to overcome these limitations. Increasing the signal averaging time would counteract motion artefacts.

Low perfusion is taken care of by maintaining minimal values for signal to noise ratio or by displaying plethysmographic wave visual index for noise. Light interference is dealt with by alternating red and infra red LED sources and deleting the ambient light signals. Other hemoglobins can be accounted for by using co oximeters.

Calibration

Since a ratio rather than absolute value is measured, photo sensors do not need any calibration. However, calibration curves programmed into the software vary from manufacturer to manufacturer and can be different in various pulse oximeters of the same manufacturer. Apart from this there could be some error in the wave length of the light emitted by the LEDs. For these reasons, same pulse oximeter and probe should be used for all saturation determination in a given patient.

Usefulness of pulse-oximetry

The following are its salient uses, with respect to neonatal practice.

1. It provides the fifth "vital parameter", besides temperature, pulse respiration and blood pressure.
2. It is a useful adjunct in the assessment of response to resuscitation.
3. It is an important measurement to aid in titration of oxygen therapy in newborns.
4. It can act as apnea monitor (indicating bradycardia and desaturation).
5. It is a valuable companion during transport of newborns
6. It may be useful in addition to Allen's test to detect ulnar artery patency.
7. Checking for endotracheal tube placement, effectiveness of bag and mask ventilation
8. To monitor for hypoxia during suction and laryngoscopy.

Pitfalls and precautions

1. Pulse oximeters are accurate mainly when the oxygen saturation is between 80 to 95%. The accuracy of pulse-oximetry is about ± 4 to 5% at or above 80% saturation. Accuracy declines below a saturation of 80%.
2. It is mandatory to have a sharp, well defined pulsatile wave form tracing with dicrotic notch, for the saturation and heart rate readings to be accurate.
3. Interference from other light sources gives erroneous readings, which can be avoided by covering the pulse oximeter probe with opaque material like aluminium foil.
4. Movement by the newborn baby may lead to a disrupted signal and artefacts.
5. Avoid compromising blood flow to the limb as well as pressure necrosis of the site, to which the probe is attached to prevent a false low readings as well as injury to patient.
6. If probe does not fit properly, the light can be shunted from the LEDs directly to photo-detector affecting the accuracy of the measurement.
7. Pulse oximeter is not reliable in conditions of severe hypotension or severe hypothermia (in such conditions an ear probe may be more reliable than a finger probe).
8. Pulse-oximetry does not take clinical impact of anemia into account; hence it is less accurate in severe anemia.
9. Currently available pulse-oximeters are unable to distinguish different types of haemoglobins. Hence, in the presence of COHb (carboxyhemoglobin) and MethHb (methemoglobin), the saturation readings may be falsely and significantly elevated, thus masking the presence of hypoxemia.
10. Always remember, pulse-oximetry reflects state of oxygenation. It has no value in estimation of adequacy of ventilation.
11. Lag monitor phenomenon- Often a fall in partial pressure of oxygen precedes the fall in oxygen saturations, by several minutes and there may be a delay in picking hypoxemia episode.
12. Response delay- although described as device for continuous real time monitoring of oxygen saturations, there is often a delay of 5-20 seconds due to signal averaging. Hence actual drop in saturations precedes the displayed drop.

The working

The most important parts of the pulse oximeter are the operating panel, display and the probe. It is mandatory to understand the keys on the operating panel of each pulse oximeter. The display style can be changed from the plethysmographic waveform to simple number format. The trend over 30 min upto 24 hours can be viewed in the form of waves or bar diagram. Trends can also be represented in the form of a table. When the pulse is presented as bar graphs: Rate at which the segments pulsate is equal to the pulse rate, the highest pulsating segment indicates strength of the pulse and the number of pulsating segments also indicates perfusion at the sensor site: the more segments, the stronger perfusion. If the bar display is less than 50%, it indicates poor quality signals.

There are different types of probes available. Disposable probes are available though expensive. Flex probes ensure good fixation and safety in neonates. Life of a flex probe is 6 months. Finger probes are sturdy and last for atleast 1 to 2 years. Clip probes can be applied over a finger but difficult to be used in neonates.

Points to remember

- (i) Desired O₂ saturation will vary according to the infant's condition. Physician should specify the desired range which is as follows:
 - Premature (1-2 week) 90-93%
 - Older neonate, especially with BPD 90-95%
- (ii) Alarm limits are kept 2% higher and lower than the desired saturation range.
- (iii) Inaccurate readings may be due to:
 - poor tissue perfusion
 - cool periphery (cold stress/hypothermia)
 - exposure of probe to light sources
 - excessive movement of limb
 - electrical interference from other equipment
 - any obstruction to blood in that limb e.g. a splint or BP cuff tied tightly
- (iv) Oxygen saturation monitors are unreliable in detecting hyperoxia at high saturation values.
- (v) The error associated with saturation monitor reading is 2% in the range of 95-100%. Therefore, a saturation reading of 96% may be as low as 94% or as high as 98%.

Finally it is important to remember that pulse-oximetry monitoring serves as a useful parameter, complementing clinical examination, rather than replacing it.