Pulse Oximeter and its role in management of Hypoxia

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Abstract

Pulse oximeters provide a cost effective and non-invasive method of assessing saturation of oxygen. It uses red and infrared light for assessing level of oxygenated haemoglobin in blood. Oxygen saturation less than 95%, patient becomes hypoxic and requires intervention to maintain oxygenation to prevent organ damage. However, in some Covid-19 cases there is a condition called happy hypoxia; where patient's SpO2 levels are low without patient developing any symptoms. Such patients deteriorate rapidly and are the leading causes of mortality in Covid-19 related cases. Use of pulse oximeters for OPD screening, door-to-door surveys in hotspot areas, screening at medical and dental hospitals has proven to be an important tool for detection of hypoxemia and reducing mortality by following proper management protocols.

This article will focus on principle, working and uses of pulse oximeter and its crucial role in screening and management of hypoxia.

Key Words : Pulse oximeter, Hypoxia, oxygen saturation.

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Introduction

Pulse oximeters are simple and relatively inexpensive devices that provides quick and painless measure of oxygen saturation. However, like most medical measuring devices, proper use and accurate interpretation should be performed by medical or paramedical personnel to avoid ambiguous information. This article reviews information regarding the correct utilization of pulse oximeter device, and also on interpretation of the results obtained. The information in this article in no way replaces the need to be familiar with guidelines on managing hypoxaemia in asthma, Chronic Obstructive Pulmonary Disease [COPD], pneumonia or other cardiorespiratory disorders.

How to use a Pulse Oximeter safely?

Pulse oximeters measure blood oxygen saturation through spectrophotometry.

Oxygen saturation is basically the amount of oxygen dissolved in blood and it is measured based on the detection of oxyhemoglobin and deoxyhemoglobin.[1] Oxyhemoglobin and deoxyhemoglobin have significant different absorptions in the red and infrared spectra. Oxyhemoglobin absorbs more of infrared spectra and very little of red spectra whereas deoxyhemoglobin absorbs more of red spectra and less of infrared spectra. Thus, pulse oximeters depend on this difference and emit two wavelengths of light, 660 nm in the red spectra and 940 nm in the infrared spectra. This light is emitted through the photodiode from one arm of the pulse oximeter, it passes through the finger to reach the detector at the opposite arm. The arterial blood volume fluctuates during the cardiac cycle, whereas the venous, capillary blood and the volumes of the rest of the tissues tends to remain the same, this assists the pulse oximeter to detect the SpO_2 of only the arterial blood.[2] The non-absorbed light is detected by the photodetector and is divided into two components: a "direct current [DC]" and "alternating current [AC]". The stable DC component refers to the light absorbed by the tissue, venous blood, and non-pulsatile arterial blood while the AC component represents the pulsatile arterial blood. It then

calculates the absorption ratio using the formula:

$$R = \frac{(Ac660)/(Dc660)}{(Ac940)/(Dc940)}$$

SpO2 is determined from a table that is stored on the memory calculated with empirical formulas. A ratio of 1 represents a SpO2 of 85 %, a ratio of 0.4 represents SpO2 of 100 %.[1]

However, a false negative result can be obtained due to false nails/ nail polish and ambient light.

Hence, the following care must be taken before performing the test.

- Nail polish should be removed from the finger that will be used for measurement. Any acrylic nails present might also adversely affect the result.
- Strong ambient light might adversely affect the readings.
- The use of correct probe type should be ensured.
- A waveform is required by pulse oximeters. Poor circulation due to cold or low blood pressure affects the readings. Also, the pulse wave may be reduced on raising the arm or squeezing the finger and affect the signal.
- A good signal on the oximeter should be ensured which could be a regular waveform or a flashing light – varies with the model.
- Manually counted pulse should be within 4-5 beats per minute of the measurement of the pulse oximeter.
- Vasodilating cream should be applied or hands should be warmed up if the signal is poor.
- The hand should be at the level of the heart and squeezing of the finger should be avoided.
- As the reading takes time to stabilise, the oximeter should be kept in place for at least a minute, or longer.[3] **(Figure I)**

Figure I- Pulse oximeter SpO_2- Oxygen saturation
PRbpm- Pulse rate (beat/minute)

Which finger is most suitable for pulse oximetry?

The index finger dominantly is supplied by the ulnar artery. But middle finger receives both ulnar and radial artery blood supply. Mizukoshi et al. have investigated the most suitable finger for the measurement of the pulse oximetric monitoring and concluded that the middle finger of dominant hand had the highest and possibly the most accurate SpO_2 measurements. Higher perfusion in the middle finger seems reasonable to expect the highest and most accurate SpO_2 value.[4] **(Figure II)**

Figure II- Test performed with middle finger of dominant hand.
SpO_2- 99% PR- 74 bpm

What is Normal?

The normal levels of oxygen saturation is at 95% or more in adults and in range of 85-90% in children.[5]

Accuracy of pulse oximeter-

The accuracy of a pulse oximeter is evaluated by the differences between the oxygen-saturation values measured by the pulse oximeter and measured by co-oximetry in extracted blood, the gold standard. Maximum manufacturers claim an accuracy of 2%. However, a greater inaccuracy in SpO_2 measurement by pulse oximeter is seen in critically ill patients, as the empirical calibration of pulse oximeters is based on examinations of healthy volunteers which might not be applicable to critically ill patients. Also, this discrepancy is accentuated in neonates.[6]

Limitations of pulse oximeter-

Limitations of oximeters may result in erroneous readings.

- Oximetry may not be able to detect hypoxemia in patients with high arterial oxygen tension (PaO2) levels, due to

the sigmoid shape of the oxyhemoglobin dissociation curve.

- High levels of COHb and MetHb adversely affect the accuracy of the readings as conventional pulse oximeters can only detect deoxyhemoglobin and oxyhemoglobin[7]
- Intravenous dyes used for diagnostic investigations, low perfusion states, pigmented patients and patients with sickle cell anemia may report inaccurate readings.[8],[9]
- Various sources of ambient light can alter the readings as they can also produce the same two wavelengths of light as those used by pulse oximeters. Fluck and colleagues used five separate ambient light sources and found the highest difference between the control and any of the light source to be less than 5%.
- Nail polish has also shown to interfere with pulse oximetry readings.[10]
- Motion of the patient is also considered as ansustantial cause of error and false alarms. To reduce the motion artifacts, various several signal processing techniques have been incorporated.
- The knowledge about the accurate use of pulse oximetry is quite restricted. A study showed 37% of critical care nurses did not know about inaccuracies due to patient motion, 15% weren't aware about the poor signal quality and 30% thought that the readings were same as that obtained from arterial blood gas analysis.[11]

Pulse oximeter Vs arterial blood gas

Arterial blood gas analysis, though provides an accurate measure of oxygen content of blood, it requires a painful arterial puncture and other limitations such as:

- It reflects only the last few minutes of cardiorespiratory function
- Expensive armamentarium is required.
- Competent personnel are required to perform the arterial stab

On the other hand, pulse oximetry is cost effective, painless and non-invasive. Monitoring change in oxygenation is pretty straight forward. However, at times it might provide inaccurate results and an inability to measure ventilation.

In the COVID-19 pandemic many fake messages on malicious apps are being circulated on social media. Fraudulent claims have come up that instead of using the oximeter, one can measure the oxygen saturation by placing the fingers or fingerprint on the mobile light using these apps. Such apps can be a threat to personal information and data being stolen and hence should be cautiously used.

Happy hypoxia

In a normal person, the blood oxygen saturation is at around 95% or more. In conditions affecting the lungs this value tends to drop below the normal level. This condition is referred to as hypoxemia.

Blood oxygen levels below 90 percent are considered to be too low and patients generally require oxygen therapy. Hypoxic patient might present with shortness of breath and chest pain. However, in happy hypoxia (also called as silent hypoxia), the person shows no such symptoms and is commonly seen in COVID-19 patients.

A pulse oximeter can be used to detect blood oxygen levels in a COVID-19 patient. Also, in conditions like pneumonia, the reduction in blood oxygen saturation levels are accompanied by fluid collection and raised carbon dioxide levels in the lungs. The latter is what makes them unable to breathe properly instead of the low blood oxygen levels.

Hypoxemia, if left unchecked, leads to a condition called hypoxia (low tissue levels of oxygen), which can cause organ damage.[12]

A study of 16 COVID-19 patients with very low levels of oxygen (as low as 50%; normal blood oxygen saturation is between 95 and 100%), without shortness of breath or dyspnoea, found that "several pathophysiological mechanisms account for most, if not all, cases of silent hypoxemia. This included the initial assessment of a patient's oxygen level with a pulse oximeter.[13]

Screening and management of happy hypoxia-

Supplemental oxygen is the first step in facilitating oxygenation. In patients with refractory hypoxemic e.g in respiratory failure (increasing shunt fraction), timely intubation and invasive ventilation support may be superior to non-invasive ventilation in boosting transpulmonary pressure. COVID-19 patients are exquisitely positive end expiratory pressure (PEEP) sensitive. Tolerance for modest permissive hypercapnia minimizes ventilator-induced lung

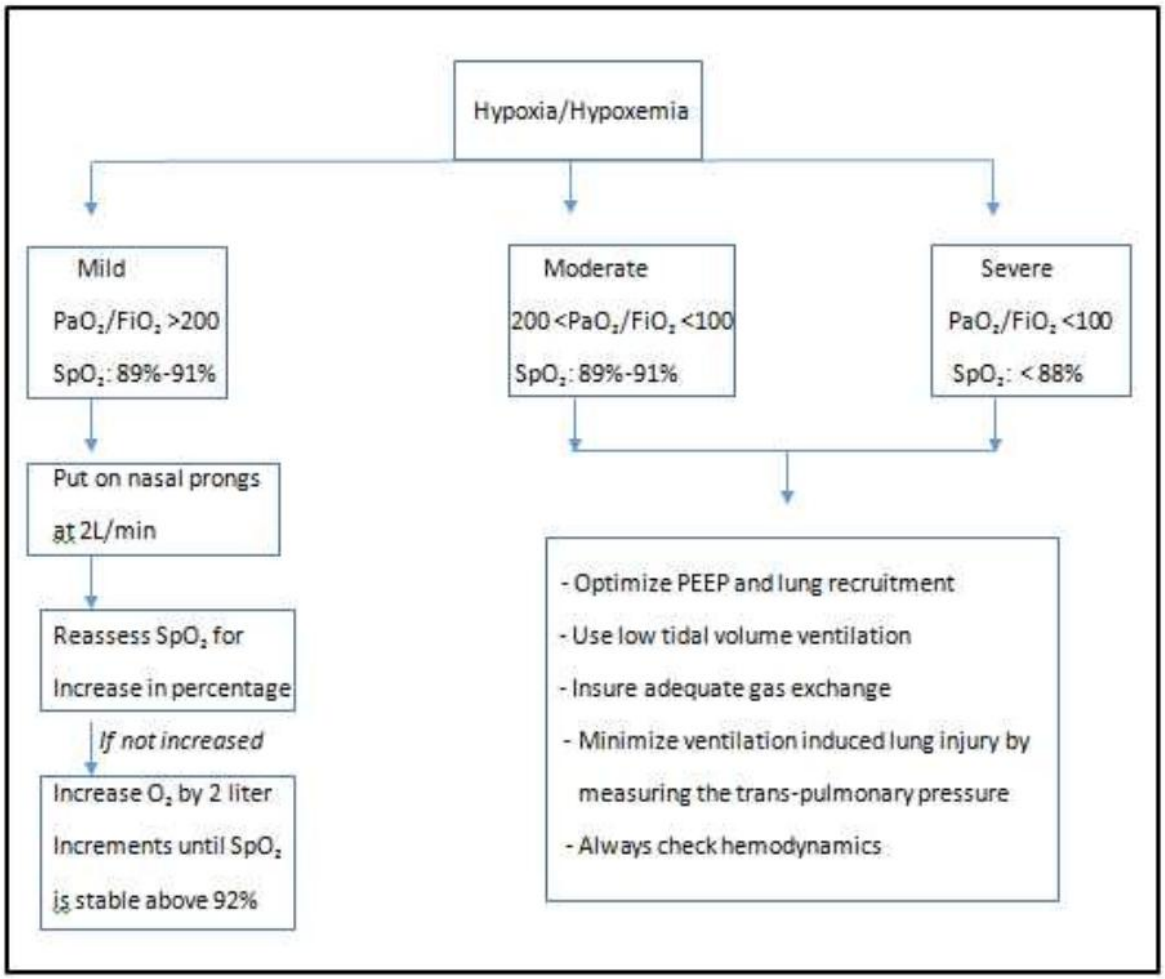

Figure III- Flowchart depicting management of hypoxia/ hypoxemia

injury (VILI). Since prone position recruits the dorsal lung regions and diverts blood flow to these caudal regions, it may have particular importance in CoViD-19 when used early and in relatively long sessions. Although further trials are needed to evaluate the impact on disease severity and mortality, several authors confirmed that awake proning can improve oxygenation in CoViD-19.[14,15] **(Figure III)**

Summary and Conclusion-

Pulse oximeters provide a cost effective, quick and non-invasive method of assessing oxygenation

There are a number of technical points which must be understood before an accurate saturation can be reliably obtained

Interpretation of the results requires an understanding of the patient's condition and importantly whether the patient is unstable and acutely unwell or whether they are in a stable phase of a chronic illness.

In relation to CoViD-19 pandemic, health department officials claimed that they were continuously checking the health of people, measuring blood oxygen levels of patients, especially in high-risk groups and living in hotspots. This is also being done while conducting door-to-door surveys in hotspot areas, also in OPDs in Medical hospitals and clinics including dental Hospitals & Dental clinics.

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Conflicts of interest

There are no conflicts of interest.

References

1. A. Chan ED, Chan MM, Chan MM. Pulse oximetry: understanding its basic principles facilitates appreciation of its limitations. Respiratory medicine. 2013 Jun 1;107(6):789-99.

2. Lopez S, Americas RT. Pulse oximeter fundamentals and design. Freescale Semiconductor, Application Note, Document Number: AN4327 Rev. 2012 Nov;2.
3. NHS Calderdale, NHS Greater Huddersfield, NHS North Kirklees and NHS Wakefield CCG. Cross cluster respiratory group in collaboration with The Mid Yorkshire Hospitals NHS Trust and Calderdale and Huddersfield Foundation Trust.
4. Mizukoshi K, Shibasaki M, Amaya F, Mizobe T, Tanaka Y. Which finger do you attach pulse oximetry to? Index finger or not? Eur J Anesthesiol. 2009; 26(suppl 45):3AP1–3AP5.
5. Schult S, Canelo-Aybar C. Oxygen saturation in healthy children aged 5 to 16 years residing in Huayllay, Peru at 4340 m. High Alt Med Biol. 2011 Spring;12(1):89-92.
6. Nitzan M, Romem A, Koppel R. Pulse oximetry: fundamentals and technology update. Med Devices (Auckl). 2014 Jul 8;7:231-9. doi: 10.2147/MDER.S47319. PMID: 25031547; PMCID: PMC4099100.
7. Buckley RG, Aks SE, Eshom JL, Rydman R, Schaider J, Shayne P. The pulse oximetry gap in carbon monoxide intoxication. Ann Emerg Med. 1994;24:252–5
8. Saito S, Fukura H, Shimada H, Fujita T. Prolonged interference of blue dye 'patent blue' with pulse oximetry readings. ActaAnaesthesiol Scand. 1995;39:268–9.
9. Comber JT, Lopez BL. Evaluation of pulse oximetry in sickle cell anemia patients presenting to the emergency department in acute vasoocclusive crisis. Am J Emerg Med. 1996;14:16–8.
10. FluckJr RR, Schroeder C, Frani G, Kropf B, Engbretson B. Does ambient light affect the accuracy of pulse oximetry? Respir Care. 2003;48:677–80
11. Jubran A. Pulse oximetry. Crit Care. 2015 Jul 16;19(1):272.
12. https://www.firstpost.com/health/happy-hypoxia-in-covid-19-new-study-may-have-found-possible-causes-behind-this-biology-defying-complication-8578751.html
13. Martin J. Tobin, Franco Laghi, AmalJubran. **Why COVID-19 Silent Hypoxemia is Baffling to Physicians**. American Journal of Respiratory and Critical Care Medicine, 2020; DOI: 10.1164/rccm.202006-2157CP
14. CLINICAL MANAGEMENT PROTOCOL: COVID-19 by Government of India, Ministry of Health and Family Welfare, Directorate General of Health Services (EMR Division) - Version 3: 13.06.20
15. Dhont, S., Derom, E., Van Braeckel, E. *et al.* The pathophysiology of 'happy' hypoxemia in COVID-19. Respir Res 2020;21:198.