



## PULSE OXIMETER USAGE IN PATIENT COVID-19 TREATMENT : AT A GLANCE

### PENGUNAAN PULSE OXIMETER DALAM PENGOBATAN PASIEN COVID-19: DALAM SEKEJAP

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**Literatur Review**  
Studi Literatur

#### ABSTRACT

**Background:** The end of 2019, Wuhan experienced an insurgence of coronavirus within two months of this prolong pandemic. Patients with Covid-19 have chance in suffering a serious damage of respiratory system, which then lead to hypoxemia. The harmful of silent hypoxemia is that either the patients are remain untreated or they will not seek any treatment at all, though their blood oxygen levels ( $SpO_2$  levels) slowly decrease. Especially those who isolated at home. Pulse oximeter is a mini device that evaluate the level of arterial blood saturation. **Purpose:** This article gives a short review about the principle, application, advantage, and disadvantage of pulse oximetry in maintaining the Covid-19 patients with hypoxemia. **Review:** Two basic principles of pulse oximetry that are important: (a) to differentiate the oxyhemoglobin ( $HbO_2$ ) and deoxyhemoglobin (HHb), (b) to get the value of  $SpO_2$  from arterial compartment blood. How pulse oximeter detects  $SpO_2$  is based on the amount of red and IR light absorbed. Pulse oximeter can detect an abnormality of respiratory system in Covid-19 patients that may cannot be detected earlier. Pulse oximeter also helps diagnosing some severe pneumonia cases. It also can be realiable to diagnose an ARDS (Acute Respiratory Distress Syndroms) if the devices are found limited (WHO, 2020). Beside the advantages of pulse oximeter, there are some erroneous of readings. **Conclusion:** Pulse oximeter is a mini device which offers many advantages over its limitations. Limitation of pulse oximeter can be early detected and overcame with an introduction evaluation of clinical conditions of each patients.

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#### ABSTRAK

**Latar Belakang:** Akhir tahun 2019, Wuhan mengalami kebangkitan virus corona dalam kurun waktu dua bulan sejak pandemi yang berkepanjangan ini. Pasien Covid-19 berpeluang mengalami kerusakan serius pada sistem pernapasan, yang kemudian berujung pada hipoksemia. Bahaya dari silent hypoxemia adalah pasien tetap tidak diobati atau mereka tidak akan mencari pengobatan sama sekali, meskipun kadar oksigen darah mereka (kadar  $SpO_2$ ) perlahan-lahan menurun. **Tujuan:** Artikel ini dapat memberikan ulasan singkat tentang prinsip, aplikasi, keuntungan dan kerugian dari oksimetri nadi dalam menjaga pasien Covid-19 dengan hipoksemia. **Tinjauan Pustaka:** Dua prinsip dasar *pulse oximetry* yang penting: (a) untuk membedakan oxyhemoglobin ( $HbO_2$ ) dan deoxyhemoglobin (HHb), serta (b) untuk mendapatkan nilai  $SpO_2$  dari darah kompartemen arteri.  $HbO_2$  dan HHb memiliki kemampuan yang berbeda dalam menyerap cahaya merah dan inframerah dekat (IR). Pulse oximeter dapat mendeteksi kelainan sistem pernapasan pada pasien Covid-19 yang mungkin tidak dapat dideteksi lebih awal. Pulse oximeter juga membantu mendiagnosis beberapa kasus pneumonia berat dan dapat diandalkan untuk mendiagnosis ARDS (*Acute Respiratory Distress Syndroms*) jika perangkat ditemukan terbatas (WHO, 2020). Selain kelebihan pulse oximeter, ada beberapa kesalahan pembacaan. **Kesimpulan:** Oksimeter pulsa adalah perangkat kecil yang menawarkan banyak keunggulan dibandingkan keterbatasannya sendiri. Keterbatasan pulse oximeter dapat dideteksi secara dini dan diatasi dengan evaluasi pengenalan kondisi klinis masing-masing pasien.

**Kata kunci:**  
Pulse oximeter, Pasien Covid-19



## INTRODUCTION

Coronaviruses were first pondered infecting only to animals, until the whole world remarked an outbreak of Severe Acute Respiratory Syndrome (SARS) in China. Many years passed, another coronavirus, Middle East respiratory syndrome coronavirus (MERS-CoV), infected people in Middle Eastern countries (Guo et al., 2020). At the closure of 2019, Wuhan experienced an insurgence of coronavirus within two months of this prolonged pandemic. The virus then was named as SARS-CoV-2 by the International Committee on Taxonomy of Viruses (ICTV) (Ouassou et al., 2020).

The condition of patients with Covid-19 can cause serious damage to the respiratory system, which then causes hypoxemia. Hypoxemia may occur because the ability of the lungs to send oxygen travels around the body is decreased. This state of hypoxemia is possibly life-threatening (Xie et al., 2020).

## LITERATURE REVIEW

Many studies suggested that patients of Covid-19 with hypoxemia experience greater mortality risk (around 1.8 to 4.0 times) than those who have the blood oxygen level controlled. Additionally, World Health Organization (WHO) reported that Covid-19 patients have been unaware of hypoxemia until they experienced respiratory damage (Chatterjee et al., 2021). They might not experience the improper function of their lungs, but they were in a hypoxemia state. There has been a bright-line report about the difference between the level of hypoxemia and the proper function of respiration. This condition may lead to "silent hypoxemia" (Xie et al., 2020). The adverse of silent hypoxemia is that either the patients are still untreated or they will not seek any treatment at all, though their blood oxygen levels ( $SpO_2$  levels) slowly decline.

Research stated that Covid-19 patients with severe cases but having  $SpO_2$  values of over 90% had a high chance of alive. On the other hand, those who have  $SpO_2$  of 90% or below, even with help of supplementary oxygen, can be life-threatening. That is why blood oxygen levels become one of the most crucial clinical parameters in predicting Covid-19 patients (Nickson et al., 2021). The National Institutes of Health also gave a suggestion to regularly maintain the levels of oxygen saturation, which the allowance level of oxygen saturation for Covid-19 patients is 92-96% (Chatterjee et al., 2021).

Maintaining the arterial oxygen saturation can be done continuously and independently by Covid-19 patients, especially those who isolate at home. The pulse oximeter is a mini device that can be used to evaluate

the level of arterial blood saturation. This article may give a short review about the principle, application, advantage, and disadvantage of pulse oximetry to maintain the Covid-19 patients.

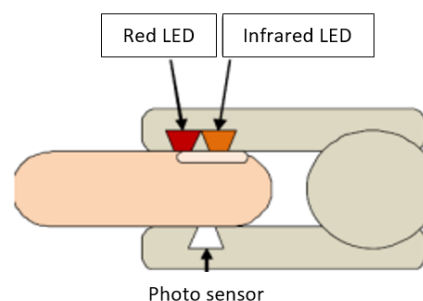
## DISCUSSION

### • Basic principle

Pulse oximetry becomes a well-known method of technology that had been used continuously long before this pandemic happened. The technology of pulse oximeter must be known as well as its limitation. Erroneous reading a result may cause a fatal diagnose. Recognizing the setting of the pulse oximeter before reading the percentage oxygen saturation help decreasing the risk in reading false estimate value of  $SaO_2$  (arterial blood oxygen levels). There are two basic principles of pulse oximetry that are important : (a) to differentiate the oxyhemoglobin ( $HbO_2$ ) and deoxyhemoglobin (HHb), also (b) to get the value of  $SpO_2$  from arterial compartment blood (Sinex, 1999).

Whilst the far-IR light is significantly absorbed by water and non-vascular tissues, the red and near-IR light absorb tissues well.  $HbO_2$  and HHb are different in their ability to absorb red and near-infrared (IR) light.  $HbO_2$  can absorb more amounts IR light than HHb., besides  $HbO_2$  have a lower ability to absorb the red light. It was the reason why  $HbO_2$  appears bright red to the eyes. It is because  $HbO_2$  scatters more red light than does HHb. Consequently, HHb absorbs more red light and expresses less red to our eyes (Sinex, 1999).

Using this significant ability in light absorption, the emission of pulse oximeter comes from two types of light wavelengths: red at 660 nm and near-IR at 940 nm. It comes from a pair of diodes that emits light located in one arm of a finger probe. The light that is delivered through the finger then ascertained by photodiode on the opposite arm of the probe (Chan et al., 2013) as seen in Figure 1 below.

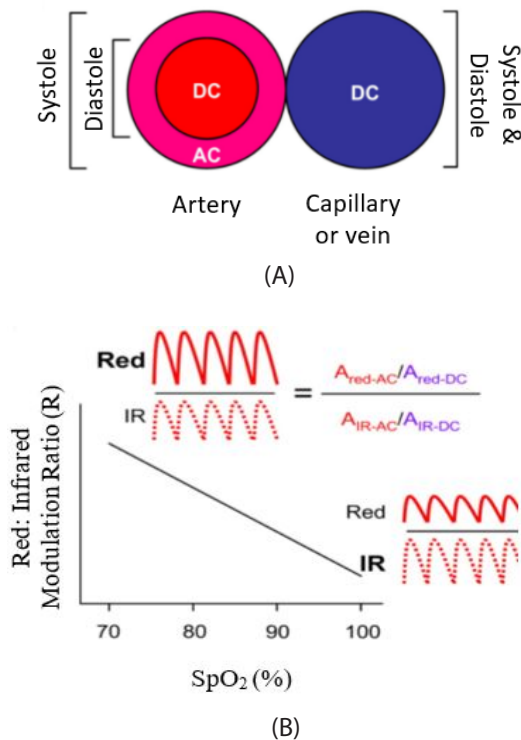


**Figure 1.** Illustration of the pulse oximeter (Chan et al., 2013)

How pulse oximeter detects  $SpO_2$  is based on the amount of red and IR light absorbed. The absorption

may fluctuate because of the increase of arterial blood volume when in systole-state and decrease when in diastole-state. A number of the light transports through the tissues then strikes the photodetector of the probe, and wherefore generate signals. The signals consist of two components: Direct Current (DC) component which is relatively stable and Alternating Current (AC) which is pulsatile. Figure 2(A) illustrated that arteries have pulsatile compartments meanwhile in veins and capillaries there is no significant volume changed.

The ratio of red: IR modulation (R) shows the values of saturation level of oxygen in arterial blood. The R ratio is a double-ratio of the pulsatile and non-pulsatile (stable) components of red light to IR light absorption. Low level of SpO<sub>2</sub>, which means Hb increased, the relative amplitude of the red light is greater than IR absorbance has. Conversely, a higher level of SpO<sub>2</sub> results in a lower IR modulation value. Diagram curve of the Red: IR Modulation Ratio in connection to the SpO<sub>2</sub> may be seen in Figure 2(B).



**Figure 2.** (A) Artery and vein diagram of two compartment (AC and DC) in a blood vessel, (B) Standart curve of R-value and SpO<sub>2</sub> (Chan et al., 2013)

### • Probes of the pulse oximeter

Finger (especially the second finger), nose, ear lobe, and forehead is the most frequent area that is used to be probes of the pulse oximeter. The skin of those areas is denser in vascular than any others. There are two types of probes: reusable clips and single-patient adhesive probes. The reusable clip probe consists of fingers, nasal, and ear while the single-patient one consists of fingers and forehead. Those two probes have their advantage and disadvantage. The reusable

ones are superior in rapidity, easiness, and also cost-effectiveness. On the other hand, the single-patient probes are automatically less infectious because it is applied on the single patient only. Moreover, there are some experimental trials-and-errors in finding the optimal probe in each case depends on the clinical circumstance (Mannheimer, 2007). The patients with covid-19, which do not experience vasoconstriction, usually use the probe which is located in the second finger.

### • Advantages in usage of the pulse oximeter

In evaluating the respiration system insufficiency state of patients, there is an arterial blood gas analysis (BGA) as a gold standard method that measures not only oxygen saturation but also the acid-base condition of the patient. With the same function (except the acid-base level), pulse oximeter offers a fast, easy, and non-costly technique. Especially for the easiness, that pulse oximeter offers about no-blood samples taken, compared to the blood gas analysis. Monitoring of hypoxemia is allowed using this moderator accurate device. This condition is the reason why a pulse oximeter can be applied in evaluating Covid-19 patients from the early stage (isolated stated) until the highest stage (ICU stated) (Joshi, 2020).

The pulse oximeter can detect an abnormality of the respiratory system in Covid-19 patients that may be not detected earlier. Reading the result of the SpO<sub>2</sub> value on the monitor display can lead to many interpretations. If the SpO<sub>2</sub> ≥ 94% followed by no chest pain, shortness of breathing, or any emergency symptoms, it is a normal state that the patients can continue monitoring themselves. If the SpO<sub>2</sub> ≤ 94%, it is a sign that patients require to be hospitalized. The last, if SpO<sub>2</sub> ≤ 90%, it indicates an emergency state that patients need to treat with intensive care (WHO, 2011). Furthermore, as we all may know that earlier detection has become an important step to save lives.

Besides the usage in Covid-19 patients, a pulse oximeter also helps to diagnose some severe pneumonia cases. It also can be reliable to diagnose an ARDS (Acute Respiratory Distress Syndromes) if the devices are found limited (WHO, 2020). After all, the usage of a pulse oximeter is also about the guidelines of therapies oxygen supplementation (ventilator) support. Those are the advantages of a pulse oximeter that make this device become the first option before BGA (Pretto et al., 2014).

### • The accuracy of the pulse oximeter

The accuracy of the pulse oximeter is measured by the differences between SpO<sub>2</sub> and SaO<sub>2</sub> values. The SpO<sub>2</sub> differs from SaO<sub>2</sub> because the SpO<sub>2</sub> is the value of oxygen-saturation values shown by the pulse oximeter while SaO<sub>2</sub> is the value from the extracted blood. Nearly all of the pulse oximeter devices stated that their devices have an accuracy of 2%. This value comes up from the

measurement of a standard deviation of SpO<sub>2</sub> and SaO<sub>2</sub>. Some other clinical studies reported that the accuracy for one-time measurement of SpO<sub>2</sub> is 3-4% while for maintaining measurement is about 2-3%. Regardless of the low value of accuracy, pulse oximeter qualifies to detect an abrupt fall of SpO<sub>2</sub> by 3-4% in either ICU or anesthesia-stated patients. That is acceptable that a significant decrease of SpO<sub>2</sub> reflects the reduction function in the respiratory system.

Although the standard deviation of those SpO<sub>2</sub> and SaO<sub>2</sub> are low, the measurement of SpO<sub>2</sub> is not equivalent compared to that SaO<sub>2</sub> value. A study by Perkins et al. (2003) stated that the correlation between spontaneous alteration of SpO<sub>2</sub> and SaO<sub>2</sub> was found reliably low ( $r = 0.6, r^2 = 0.37$ ) conclude that they are not depending on one another (Nitzan et al., 2014).

As the result, the normal value of SpO<sub>2</sub> is cut-off to around 93% as a baseline to diagnose hypoxemia. It is because the normal value of SaO<sub>2</sub> is 90% to make both parallel each other (Joshi, 2020). From that clinical point of view, if all of those aspects are reported together with the pulse oximeter's benefit, pulse oximetry is considered critical care.

#### • Limitation of the pulse oximeter

Together with the advantage of pulse oximetry reported, there is some awareness of its limitations while using this device. It is noted that the pulse oximeter does not require a calibration system. Therefore, the users need to be aware that this device may give false readings several times (Mannheimer, 2007). The physiologic condition and background of the patients that are going to be evaluated become the most crucial understanding before using this device.

The pulse oximeter can display either the falsely low or high SpO<sub>2</sub> value. It can be caused by many factors, as the unreliable side of pulse oximeter appears. The SpO<sub>2</sub> value reading should be considered an estimation, not that accurate. For an instance, if a pulse oximeter shows 90% value, it means that the real value of oxygen saturation is about 86-94% (FDA, 2021).

False high or false normal value of SpO<sub>2</sub> can be happened to the patient with carbon monoxide poisoned. As we may know that CO has stronger avidity to Hb, which is about 240 times stronger than with O<sub>2</sub>, form a COHb molecule. In case of the ability to absorb the red light of COHb and O<sub>2</sub>Hb are not different, the photodiode of the pulse oximeter cannot make any filtration. As the consequence, the red light will be absorbed more by the combination of COHb and O<sub>2</sub>Hb. The other condition that may cause false normal or high value is sickle cell anemia case.

The other limitation of a pulse oximeter is falsely low readings, which happened more often in many cases. The venous pulsation, which causes venous volume change in the cardiac cycle, happens when the probe is set too tight at the second finger. Patients with tremor disorder, or other excessive movement disorders,

can be detected falsely low. Last, many reports stated that fingernail polish, especially black, green, or blue color decreases the value of SpO<sub>2</sub> by 10%. Newer types of pulse oximeter may be modified so that the effect can be minimized, but the reduction of SpO<sub>2</sub> value is around 2% (Chan et al., 2013).

Since the high rate of infection of Covid-19, the hygiene of user before using pulse oximeter is very recommended. Disinfecting and cleaning the probe with the alcohol swab after using the pulse oximeter is conducted to prevent the infection.

## CONCLUSION

The pulse oximeter is a mini device that can be used to evaluate the level of arterial blood saturation. Two basic principles of a pulse oximeter that have to be known are the difference of HbO<sub>2</sub> and HHb also how to generate the SpO<sub>2</sub> value from the arterial blood. Compared to the gold standard method, blood gas analysis, the pulse oximeter bring fresh innovation to measure the level of oxygen saturation. Besides the advantages, the limitations we should notice are about the preliminary study or evaluations of clinical aspects of patients, falsely readings according to many aspects, and also about the hand hygiene of the user in infectious conditions.

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