# Understanding Pulse Oximetry Can Aid in Diagnosis

BY JAMES R. ROBERTS, MD

Emergency physicians evaluate a patient's hemoglobin oxygen saturation many times per shift, using the information as a vital sign. We essentially make important clinical decisions based on real-time readings obtained by a pulse oximeter. The intricacies and mechanisms of the pulse oximeter process, however, are unknown by most who use them.

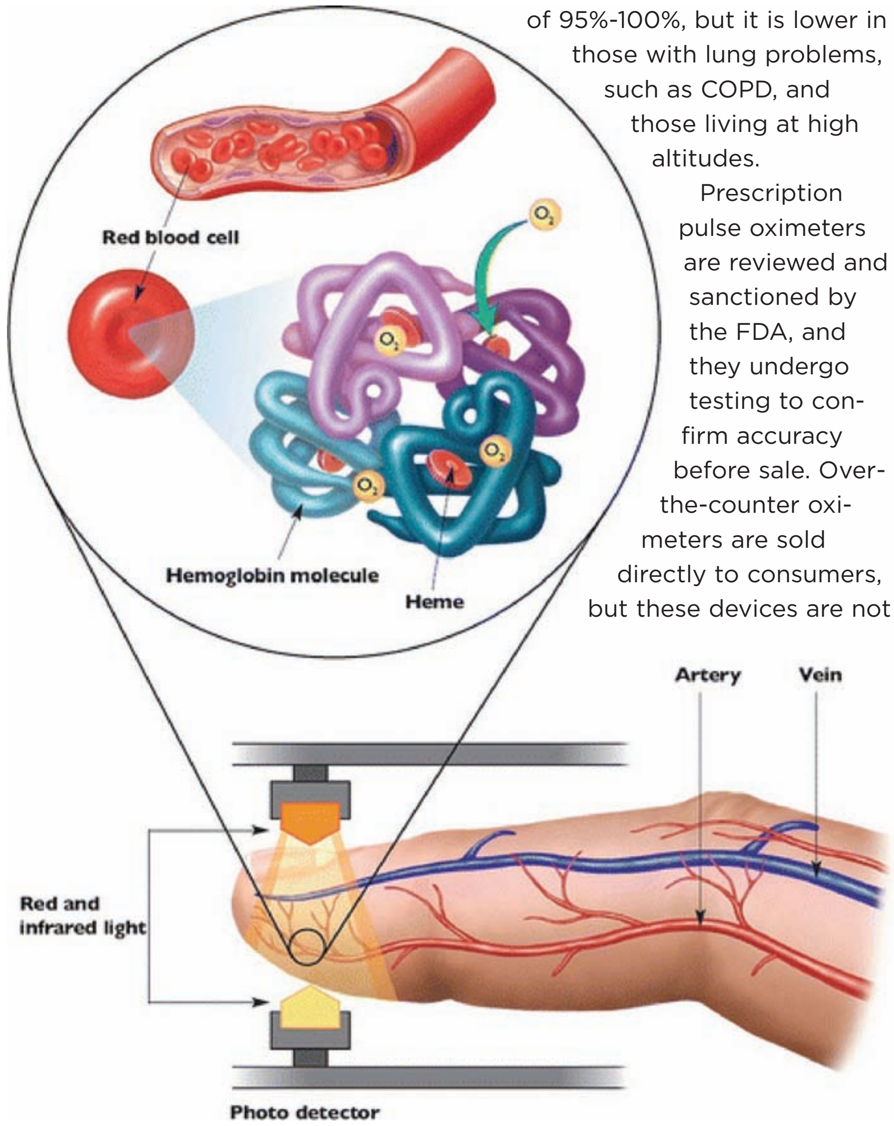
The pulse oximeter probe is simply placed on the patient, the hemoglobin's oxygen saturation is displayed on the oximeter screen, and clinical decisions and interventions are often made in a few seconds. Even home oxygen saturation measurements are becoming common because of COVID-19, a disease that primarily affects the lungs.

The harmful effects of excessive oxygen are well known to EPs. The common routine reflex is to use high concentrations of inhaled oxygen to produce 100% hemoglobin saturations. Physicians often seem bent on producing hyperoxygenation, but this outcome has been questioned. Oxygen can clearly be a toxin, and its use should be titrated to avoid hyperoxia.

Hyperoxia can be detrimental to neonates and adults suffering from myocardial infarction, and it can readily occur without monitoring. Aiming to obtain 100% oxygen saturation of hemoglobin on all patients used to be a common goal, but this can be a mistake, and titrating the oxygen treatment of all patients can avoid hyperoxia. These goals and mandates are best accomplished using a pulse oximeter.

**Pulse Oximeter Accuracy and Limitations: FDA Safety Communication**
U.S. Food and Drug Administration
Feb. 19, 2021
https://bit.ly/3CUL4do

This communication was sent to physicians to update the use of pulse oximetry, including the limitations and possible inaccuracies of the process. A marked increase in the use of the pulse oximeter has occurred because of COVID-19, and this alert includes some common-sense instructions to patients on using pulse oximeters at home.




Lippincott Williams & Wilkins, 2018

**The pulse oximeter takes advantage of the different absorption characteristics of red light and infrared light by different forms of hemoglobin. Red light and infrared light emitted by the device passes through the capillary bed and is analyzed by a photodetector. The absorption characteristics of these two emitted wavelengths by oxygenated and deoxygenated blood are evaluated by the pulse oximeter and used to calculate arterial hemoglobin oxygen saturation. Note that the light source is placed over the fingernail, not the fat pad.**

Pulse oximeters are least accurate when hemoglobin oxygen saturations are less than 80%. Pulse oximeter readings should be used only as an estimate of arterial blood oxygen saturation, and a reading of 90% actually represents arterial blood saturations of 86%-94%. Clinical decisions are based on trends in oximeter readings over time rather than a single reading.

The pulse oximeter is usually placed on a fingertip, and it uses light beams to estimate the oxygen saturation of a patient's hemoglobin, reflecting the amount of oxygen carried in the blood. Pulse oximeters also report pulse rate. The true analysis of hemoglobin oxygen saturation is made using a blood sample. Most healthy individuals have an oxygen saturation of 95%-100%, but it is lower in those with lung problems, such as COPD, and those living at high altitudes.

Prescription pulse oximeters are reviewed and sanctioned by the FDA, and they undergo testing to confirm accuracy before sale. Over-the-counter oximeters are sold directly to consumers, but these devices are not FDA-reviewed and should not be used for medical purposes.

It is important to understand the limitations and risks of possible inaccuracies of results reported on the oximeter screen. Unrecognized low oxygen saturations can be clinically important. FDA-cleared prescription pulse oximeters are evaluated by desaturation studies done on healthy individuals. Testing compares pulse oximeter saturation readings with arterial blood gas saturation readings for values between 70% and 100%. The oximeter readings must be within 2%-6% of arterial blood gas values to be certified. But oximeter readings are only an estimate of oxygen saturation, so the true oxygen saturation in the blood is generally between 86% and 94% if an FDA-cleared pulse oximeter reads 90%.

Pulse oximeter accuracy is highest at a saturation of 90%-100%, intermediate at 80%-90%, and lowest below 80%. Accuracy varies between light and dark skin pigmentation, and Black patients have nearly three times the frequency of occult hypoxemia detected by blood gas analysis but not by pulse oximetry than white patients. (*New Engl J Med.* 2020;383[25]:2477; https://bit.ly/3CTdAMs.) The FDA recently required that oximeter analysis includes the effect of skin pigment on accuracy. It is important for physicians to recognize that low oxygen saturations in Black patients may not be recognized by older pulse oximeter machines.

**Comment:** Pulse oximetry is a noninvasive measurement of the percentage of hemoglobin bound to oxygen. The device provides real-time estimates of the arterial blood oxygen saturation in the range of 80%-100%. It gives an early warning of diminished capillary perfusion without the risk and time required for an arterial blood vessel puncture and use of the hospital's lab. It relies on the concept that the concentration of an unknown substance (oxyhemoglobin) dissolved in a solvent (blood) can be determined by light absorption.

The probe used in the process is a reusable clip or disposable patch containing two photodiodes that produce a red light and an infrared light detected by a photodetector, which is placed over a pulsatile vascular bed. Single-use clips are now available for infection control.

Lippincott Williams & Wilkins, 2010

**A probe can be used on the forehead, toes, and earlobes. A headband is used to secure the probe in the proper position when used on the forehead.**

The vascular bed analyzed is usually under the nailbed, not the fat pad, but blood from the earlobe, toe, or forehead can also be analyzed.

The absorption characteristics of the two emitted wavelengths are quite different for oxyhemoglobin and reduced hemoglobin. The substance to be analyzed is determined by wavelength of the light source. Pulse oximetry is based on the principle that oxygenated hemoglobin and deoxygenated hemoglobin absorb red and infrared light differently. The absorption characteristics of skin, connective tissue, bone, and venous blood remain constant. Oxygenated hemoglobin absorbs greater amounts of infrared light and lower amounts of red light than deoxygenated hemoglobin does. Well-oxygenated blood, with its higher amounts of oxygenated hemoglobin, appears bright red on visual examination because it scatters more red light than does deoxygenated blood, which absorbs red light. Deoxygenated blood with its higher amount of red light-absorbing hemoglobin does not appear bright red on visual inspection.

The relative amounts of red and infrared light absorbed by the two types of hemoglobin are used by the pulse oximeter to determine the proportion of hemoglobin bound to oxygen. The ability of pulse oximetry to detect hemoglobin oxygen saturation in only arterial blood is based on the principle that the amount of red and infrared light absorbed fluctuates with the cardiac cycle or the pulse. The small increase in the volume of arterial blood in the fingertip that is produced by each cardiac contraction results in a change in absorption over baseline absorption of oxyhemoglobin and reduced hemoglobin because of the increased volume of arterial blood in the fingertip with each heartbeat.

The ratio of oxyhemoglobin to reduced hemoglobin can be calculated by comparing the ratio of pulsatile and baseline absorption at the two wavelengths. The pulse oximeter uses this ratio calculated over a series of pulses coupled with a calibration curve that was generated by analysis of blood taken from volunteers with various hemoglobin oxygen saturations to determine the hemoglobin oxygen saturation in the specific individual being studied.

Lippincott Williams & Wilkins, 2016

**This pulse oximeter has a reusable finger probe, calculates the arterial oxygen saturation of the blood in the finger, and can be used for continuous evaluation. The device reports oxygen saturation of normal hemoglobin, and is not used to evaluate patients with carbon monoxide poisoning or methemoglobinemia. The reported results can be falsely high or low due to numerous conditions and altered physiologic states that the physician must appreciate. Oxygen itself can be a toxin, and hyperoxygenation should be avoided because high concentrations of oxygen have recently been shown to affect the patient adversely.**

**Pulse Oximetry: Understanding Its Basic Principles Facilitates Appreciations of Its Limitations**
Chan ED, Chan MM, Chan MM
*Respir Med.*
2013;107(6):789
https://bit.ly/2ZwqJfZ

This is a well-written review article on the principles of pulse oximetry that should be read in its entirety to appreciate its message. It discusses the basic principles of pulse oximetry and reviews various conditions that can cause spurious readings and the mechanisms underlying them. The basic concept of pulse oximetry's ability to detect oxygen saturation in only arterial blood is based on the fact that the amount of red and infrared light absorbed by blood fluctuates with the cardiac cycle with measurable changes in red light and infrared light absorbance that occur as blood volume under the probe changes with each heartbeat. The pulse oximeter therefore excludes the influence of venous blood and other stationary tissues from its calculations.

The pulse oximetry probes, either a reusable clip or single-use adhesive probe, interrogate the finger, nose, earlobe, or forehead, areas with a high vascular density. The ear and forehead probes are more reliable in hypotensive vasoconstricted patients or in hypothermia because these sites are less likely to vasoconstrict than the fingers in response to endogenous and exogenous catecholamines.

The pulse oximeter will report a falsely normal or elevated oxygen saturation for some conditions. The true effect is usually minimal and is reduced by newer machines for the most part. Carbon monoxide poisoning, for example, produces carboxyhemoglobin, which has similar light absorption characteristics to oxygenated hemoglobin so the pulse oximeter cannot differentiate between the two. The pulse oximeter that utilizes only two light beams will report a normal oxygen saturation even with significant amounts of carboxyhemoglobin.

False readings also caused by a finger probe include the presence of venous pulsations from a too tightly bound probe, severe tricuspid regurgitation, pigmented dyes such as methylene blue, indigo carmine used to detect amniotic fluid leaks, indocyanine used to assess hepatic function, and excessive patient movements such as those seen with seizures or patient tremors. Newer models of pulse oximeters do not report falsely low concentrations previously reported due to nail polish, but it is best to remove the polish on the finger used by the probe. The effect of artificial fingernails varies, and it may also be best to remove an artificial nail on the finger evaluated. Severe anemia, methemoglobinemia, sulfhemoglobinemia, severe hyperbilirubinemia, and bright ambient light can cause false readings. Fetal hemoglobin has red light and infrared light absorption similar to that of normal adult hemoglobin, so a pulse oximeter is as reliable in newborns as in adults. **EMN**

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**Learning Objectives for This Month's CME Activity:** After participating in this CME activity, readers should be better able to explain how a pulse oximeter measures oxygen saturation in a patient's hemoglobin.

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