SpO2 Monitoring

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Introduction

The body's need for oxygen is certain. Its availability at a tissue level is sometimes in doubt. Blood gas measurements provide critical information regarding oxygenation, ventilation, and acid-base status.

However, these measurements only provide a snapshot of the patient's condition taken at the time that the blood sample was drawn. It is well known that oxygenation can change very quickly. In the absence of continuous oxygenation monitoring, these changes may go undetected until it is too late.

Pulse oximeters measure blood oxygen saturation noninvasively and continuously.

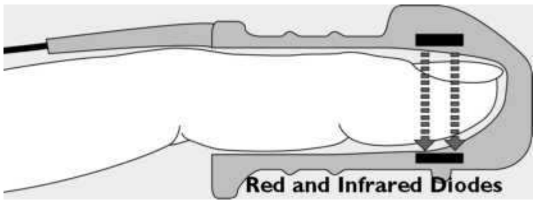
What is SpO_2?

A blood-oxygen saturation reading indicates the percentage of hemoglobin molecules in the arterial blood which are saturated with oxygen. Readings vary from **0** to **100**%. Normal readings in a healthy adult, however, range from **94**% to **100**%.

The term SpO_2 means the SpO_2 measurement determined by pulse oximetry. As explained in the section "Considerations When Using Pulse Oximetry," under some circumstances pulse oximetry gives different readings, and the use of a different term indicates this.

How Does Pulse Oximetry Work?

Within the SpO_2 sensor, light emitting diodes shine red and infrared light through the tissue. Most sensors work on extremities such as a finger, toe or ear. The blood, tissue and bone at the application site absorb much of the light. However, some light passes through the extremity. A light-sensitive detector opposite the light source receives it.



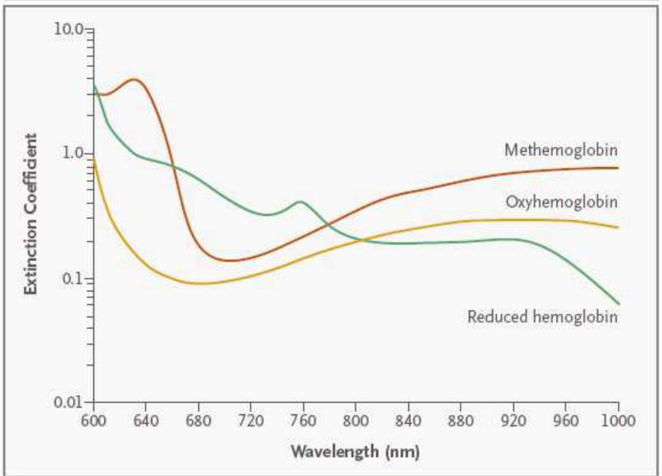


Figure 1. Extinction Curves for Various Hemoglobin Species.
Oxyhemoglobin and reduced hemoglobin have different absorptions at 660 and 940 nm, whereas methemoglobin has similar absorption at the two wavelengths. The extinction coefficient is shown on a logarithmic scale.

SpO_2 Sensors

Most sensors work on extremities such as a finger, toe or ear. The sensor measures the amount of red and infrared light received by the detector and calculates the amount absorbed. Much of it is absorbed by tissue, bone and venous blood, but these amounts do not change dramatically over short periods of time.

The amount of arterial blood does change over short periods of time due to pulsation (although there is some constant level of arterial blood). Because the arterial blood is usually the only light absorbing component which is changing over short periods of time, it can be isolated from the other components.

Absorption at the Sensor Site

The amount of light received by the detector indicates the amount of oxygen bound to the hemoglobin in the blood. Oxygenated hemoglobin (oxyhemoglobin or HbO_2) absorbs more infrared light than red light. Deoxygenated hemoglobin (Hb) absorbs more red light than infrared light. By comparing the amounts of red and infrared light received, the instrument can calculate the SpO_2 reading.

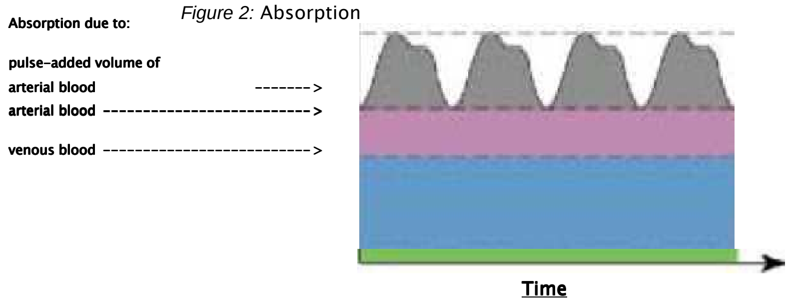


Figure 2: Absorption

Oxyhemoglobin Dissociation Curve

You may have used oxygen partial pressure (PaO_2) to judge oxygen saturation. SpO_2 is related to PaO_2 in a complex way, as shown in Figure **3**, the Oxyhemoglobin Dissociation Curve.

At very high SpO_2 levels, PaO_2 values can vary widely without producing a significant change in SpO_2 levels. Because of this, SpO_2 readings cannot be used to warn of high PaO_2 levels.

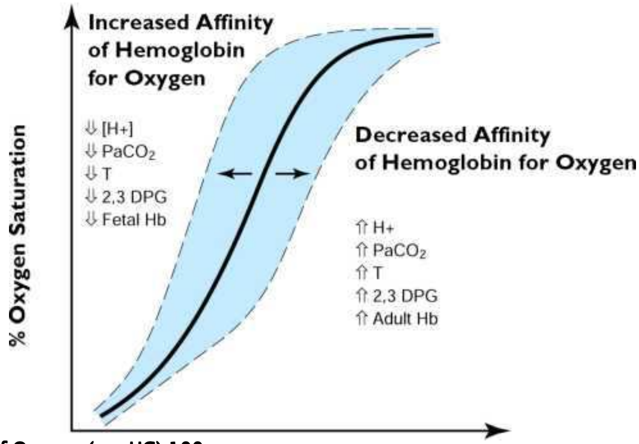
Many variables can affect hemoglobin's affinity for oxygen, and thus the position of the curve. Decreasing concentrations of hydrogen ions, $PaCO_2$ and 2,3 DPG, increase hemoglobin's affinity for oxygen and shift the curve to the left.

An increase in the variables shifts the curve to the right. Fetal hemoglobin, which binds more readily with oxygen than adult hemoglobin, also affects the curve, as does temperature.

The relationship between SpO2 and PaO2 is not simple, so judging one measurement from the other should only be attempted with caution. Using pulse oximetry is fairly simple. Many questions may be answered by referring to your instrument's *Instructions for Use*.

Figure 3: Oxyhemoglobin Dissociation Curve

100%



0 Partial Pressure of Oxygen (mmHG) 100

How Do I Use SpO2?

Choosing a Sensor

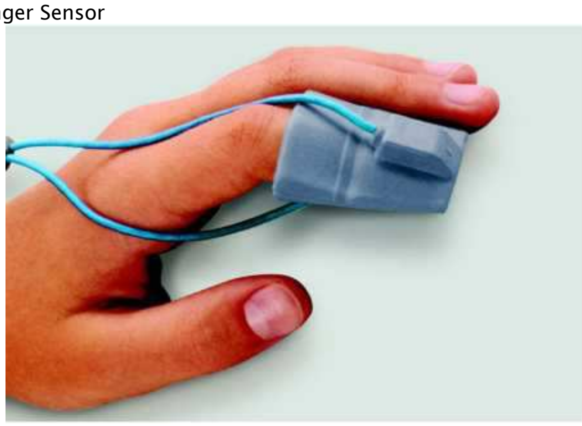
There are some general guidelines to choosing the right sensor. The ideal application site has good perfusion, does not generate movement artifact, is comfortable for the patient and allows easy application.

The size of the application site determines what size sensor to use. The age of the patient is not a factor.

If a sensor is too big or too small, the light emitting diode and the light detector may not line up. This could cause a false reading or an alarm.

If a finger sensor is too large, it may slip partway off so that the light source partly covers the finger. This condition, called optical bypass, causes incorrect readings.

Figure 4: Pediatric Finger Sensor



If a finger is inserted too far into the sensor it may be squeezed by the sensor, which causes venous pulsation. The pulse oximeter recognizes arterial blood only by its pulsing motion, so in this case it also measures venous blood. This causes readings which are falsely low.

Using SpO2

Because pulse oximetry provides continuous monitoring and is noninvasive, it may be useful in several clinical situations.

Surgery and Post Anesthetic Care Units

Since pulse oximetry provides a means of continuously assessing of the oxygenation of the patient, many require it. If ventilation fails, an alarm sounds.

Additionally, SpO_2 is noninvasive so it is safer and more pleasant for the patient than invasive methods of oxygen analysis.

Neonatal Care and NICU

Blood-oxygen saturation levels taken immediately after birth, preferably on the right hand, (within five minutes) are a good guide to the neonate's general state of health. Levels below **75**% may indicate abnormalities. Together with Apgar scores, blood-oxygen saturation readings are very useful. Both too little or too much oxygen is dangerous for the neonate, particularly for the premature neonate.

Oxygen partial pressure (PaO_2) is most critical for the neonate. Although blood-oxygen saturation and PaO_2 are related, there are too many other factors involved to convert easily between the two measurements. Refer to the “Oxyhemoglobin Dissociation Curve” on page 3 for more details.

Emergency Care

In emergent care situations, both in and out of the hospital, patients may need ECG monitoring, SpO2 monitoring, pacing and defibrillation at a moment's notice.

Noninvasive Transcutaneous Pacing

Pulse oximetry, as integrated into Philips’ defibrillator/monitors, provides a tool to help determine whether pacing is effective.

You can use the SpO2 measurements in addition to the patient's ECG signal as shown on the monitor to verify that mechanical capture has been achieved.

When the patient is being successfully paced, the pulse rate derived from the pulse oximeter, the ECG heart rate derived from the ECG monitor and the pacing rate should all be about the same. In addition, there should be signs of improved cardiac output.

Recorded strips provide a printed record of SpO_2 measurements and SpO_2 alarm violations during pacing.

Considerations When Using Pulse Oximetry

Blood oxygen saturation is a measure of the amount of oxygen carried by hemoglobin in the blood stream. It is usually expressed as a percentage rather than an absolute reading. Pulse oximeters define this percentage in a different way than other instruments. These subtle, but important differences, are described in the following section.

Effects of Non-functional Hemoglobin on Oxygen Saturation Measurements

In order to judge a patient's condition, ideally you would like to have blood oxygen saturation expressed as a percentage of the total hemoglobin that is saturated with oxygen. Under many circumstances, that is the reading you get from pulse oximeters. However, if the patient has a large amount of nonfunctional hemoglobin, the reading is not accurate. Non-functional hemoglobin is defined as hemoglobin which is incapable of carrying oxygen, but does include carboxyhemoglobin (HbCO) and methemoglobin (METHb). Functional hemoglobin is defined as hemoglobin capable of carrying oxygen. It includes oxygenated hemoglobin (HbO_2) and deoxygenated hemoglobin (Hb).

In other words, the ideal blood saturation measurement is:

$$100 \times \frac{HbO_2}{Hb + HbO_2 + HbCO + METHb + \text{other non-functioning hemoglobins}}$$

where Hb is hemoglobin, HbO_2 is oxygenated hemoglobin, HbCO is carboxyhemoglobin, and METHb is methemoglobin. This is also referred to as fractional saturation.

Pulse oximeters usually assume there are no non-functioning hemoglobins in the arterial blood and measure the blood oxygen saturation as:

$$100 \times \frac{HbO}{Hb + HbO_2}$$

When the amount of non-functioning hemoglobin (represented above by HbCO + METHHb + other non-functioning hemoglobins) is very small, both readings are nearly the same.

When the patient has large amounts of non-functioning hemoglobin, these measurements vary widely. Several situations can lead to such large amounts of non-functioning hemoglobin. Carbon monoxide poisoning and even heavy smoking increase the amount of carboxyhemoglobin, a non-functioning hemoglobin.

Other Situations

Pulse oximetry is a very useful technology, but there are situations where you must be careful in applying it. Keep the following in mind when you use a pulse oximeter.

Anemia

Damage to red blood cells may cause anemia, a lack of red blood cells and thus hemoglobin in the blood. An anemic patient may not have enough functioning hemoglobin in the blood to oxygenate the tissues. The small amount of functioning hemoglobin in the blood may be well saturated with oxygen, so the patient may have a normal SpO_2 reading, but the patient may not have enough oxygen going to the tissues.

Dyes

Some surgical procedures, especially in cardiology and urology, call for the injection of dyes into the blood in order to trace blood flow.

These dyes affect light transmission through the blood. They directly influence the pulse oximeter and lead to wrong readings.

If the patient's blood contains any of the following dyes, you cannot use pulse oximetry to measure oxygenation:

- Methylene blue

- Indiocyanine green
- Indiocarmine

Bilirubin, a breakdown product from red blood cells, does not affect readings from pulse oximeters.

Perfusion

SpO_2 is always measured at one of the body's peripheral sites: a finger, toe or ear. The site chosen for the SpO_2 measurement must be adequately perfused with blood.

Shock

The body reduces blood supply to the limbs and extremities as a response to injury, or even the fear of injury, to maintain the blood supply to vital organs even in the event of severe blood loss. Because of this reduced perfusion, pulse oximeters may give misleading readings on patients in severe shock.

Hypothermia

The body reduces the heat lost by the skin by constricting the peripheral blood vessels.

Cold is a common problem, often seen with car accident victims and patients undergoing brain or open heart surgery during which body temperature is lowered. Cold also causes shivering, which can lead to movement artifacts.

Common Problems with Pulse Oximetry

Although a pulse oximeter is easy to use, there are common problems associated with the use of oximeters.

Light Interference

Sometimes external light sources may cause inaccurate readings. If you suspect that a light may be causing interference, try covering the site with an opaque material and see if the reading changes. If so, keep the site covered.

Movement Artifacts

Movement artifacts, such as shivering, have been overcome with the latest SpO_2 algorithms, such as Philips FAST-SpO_2. However, unusually strong movement may cause movement artifact in the pulse. Apply the sensor to a less susceptible site if possible.

Sensor application

The sensor should fit the application site snugly. If it is too tight, it might cause venous pulsation. If it is too loose, the light issuing from the emitters may not pass completely through the site and may cause erroneous readings.

If adhesive sensors are not the right size, the emitter and detector may not line up correctly. Make sure you use the correct sensor for the patient to get the most accurate reading.

Inadequate Blood Flow

Blood pressure cuffs, tight clothing or restraints may interfere with blood flow. Use another application site or loosen clothing.

Nail Polish

Some nail polish and false fingernails may cause false readings. If possible, switch to an unpolished nail, or consider another application site.

Glossary

Blood-oxygen Saturation

The amount of oxygen bound to hemoglobin in the blood, expressed as a percentage. **Functioning**

Hemoglobin

Hemoglobin which is capable of carrying oxygen. Functioning hemoglobin includes oxygenated hemoglobin (HbO2) and deoxygenated hemoglobin (Hb).

Movement Artifacts

Motion of the blood caused by patient motion instead of pulsation. **Non-functioning**

Hemoglobin

Hemoglobin which is not capable of carrying oxygen. Non-functioning hemoglobin includes carboxyhemoglobin (HbCO) and methemoglobin (METHb).

Pulse Oximetry

The technique of measuring oxyhemoglobin saturation by shining red and infrared light through a peripheral site, such as a finger, toe, or nose.

SaO2

A measurement of oxygen saturation in arterial blood.

SpO2

Oxygen saturation in arterial blood as measured by a pulse oximeter. SaO_2 and SpO_2 readings differ because pulse oximetry measures the oxygen saturation of only functional hemoglobin. SaO_2 readings indicate the saturation of both functional and nonfunctional hemoglobin.