Pulse oximetry

For patients at a risk of respiratory failure it is important to monitor the efficiency of gas exchange in the lungs, i.e., how well arterial blood is oxygenated. Pulse oximetry is not invasive technique now well established in clinical use during anesthesia and intensive care.

The principle of pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated (HbO_2) and deoxygenated - reduced hemoglobin (Hb). Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through. Deoxygenated hemoglobin absorbs more red light and allows more infrared light to pass through. It is possible to use the difference in absorption spectra of HbO_2 and Hb for the measurement of arterial oxygen saturation *in vivo* because the wavelength range between 600 – 1000 nm is also the range for which there is the least attenuation of light by body tissues (tissues and pigmentation absorb blue, green and yellow light and water absorb longer infra-red wavelength). The **isobastic point** is the wavelength at which the absorption by the two forms of the molecule is the same. These points may be used as reference points where light absorption is independent of the degree of saturation

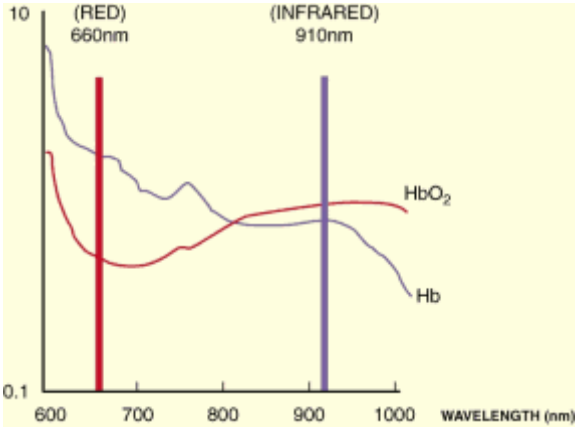
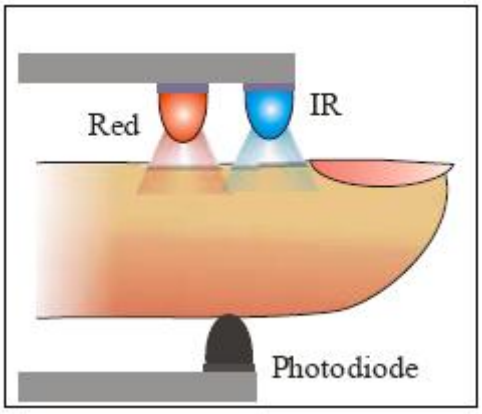


Figure Absorption spectra of Hb and HbO_2.

Pulse oximetry uses a light emitter with red (usually 650 nm) and infrared (usually 950 nm) LEDs that shines through a reasonably translucent site with good blood flow. Typical adult/pediatric sites are the finger, toe, pinna (top) or earlobe. Infant sites are the foot or palm of the hand and the big toe or thumb. Opposite the emitter is a photodetector that receives the light that passes through the measuring site.

Oxygen saturation, which is often referred to as SaO_2 or SpO_2, is defined as the ratio of oxyhemoglobin to the total concentration of hemoglobin present in the blood (i.e. oxyhemoglobin + reduced hemoglobin). Arterial SpO_2 (parameter measured with oximetry) is normally expressed as percentage. Under normal physiological conditions arterial blood is saturated to 97%, while venous blood is saturated to 75%.



Pulse oximetry assumes that the attenuation of light by body segment can be split into three independent components shown in figure: arterial blood, venous blood and tissues. Oximeter has the potential to get confused because it doesn't know how much light is absorbed by blood and how much is absorbed by the tissues surrounding blood. The pulse oximeter wants to only analyse arterial blood, ignoring the other tissues around the blood. Luckily, arterial blood is the only thing pulsating in the finger (DC signal). Everything else is non-pulsating (AC signal). Any "changing absorbance" must therefore be due to arterial blood. On the other hand, the pulse oximeter knows that any absorbance that is not changing, must be due to non-pulsatile things such as skin and other "non - arterial" tissues. The computer of oximeter subtracts the non changing part of the absorbance signal from the total signal. After the subtraction, only the "changing absorbance signal" is left, and this corresponds to the pulsatile arterial blood. In this way, the pulse oximeter is able to calculate the oxygen saturation in arterial blood while ignoring the effects of the surrounding tissues.

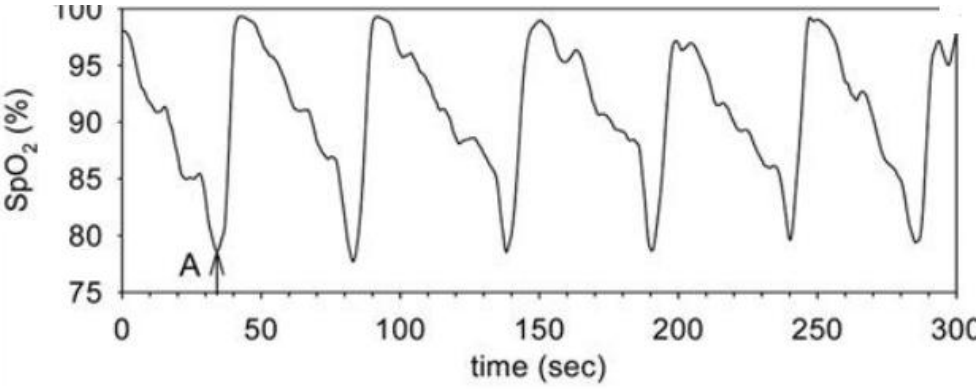


Figure Typical pulsatile signal detected when light is shone through a finger.

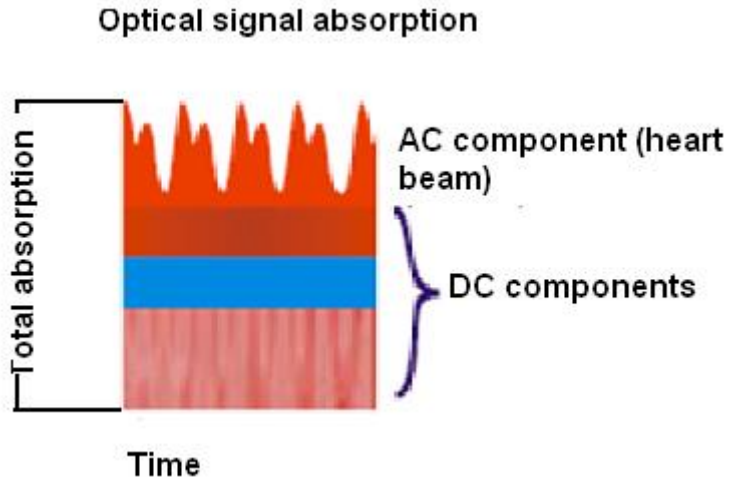


Figure The AC and DC pulsatile signals.

The dye, methylene blue, if in the patient's circulation, will artificially lower the displayed oxygen saturation. Finger nail polish can also affect the accuracy of saturation determination. Abnormal hemoglobin can affect pulse oximeter readings. Carbon monoxide combines with hemoglobin to form carboxy hemoglobin (COHb), which absorbs almost identically to HbO, at 660 nm. Most pulse oximeters cannot separately detect COHb. Instead, it considers carboxy Hb as oxy hemoglobin. This is dangerous as COHb doesn't carry oxygen, and the artificially high oxygen saturation displayed may wrongly reassure everyone (for instance if a patient had 90% HbO, 7% COHb, and *3%* Hb, a pulse oximeter would read SpO, = 97%).

Methemoglobin, the abnormal form of hemoglobin, in which the iron in the heme group is in the Fe^{3+} (ferric) state, not the Fe^{2+} (ferrous) so that it cannot bind oxygen, has approximately the same absorption coefficient at 660 and 940 nm. Oximeters interpret this 1: l absorption ratio as corresponding to a SaO_2, of 85%.

Exercise: Measure the arterial oxygen saturation (SpO_2) and pulse rate (PR).

Procedure:

1) Place the SpO_2 sensor cable on the backside of a patient finger.
2) Read and write SpO_2 and PR values for a patient rest (the measurement should be done at least 15 sec). Check the values of the indexes IQ a PI and evaluate the truthness of your measurement.
3) Make some physical exercise (squats) and monitor the changes of SaO2 saturation. When the value stabilized write down the values of SpO_2 and PR. Explain the changes.
4) After finishing measurement of one patient place the SpO_2 sensor cable on the backside of a second patient finger. He will do all the measurements according the points 2 and 3.
5) When all the patients have measured their SpO_2 and PR values, turn off the unit according the instructions in manual.
6) Loosen the patient cable. Press both disconnect buttons at the plug connector of the patient cable together and remove the connector.
7) Start PC, connect the unit with the USB cable to the PC.
8) Select the new patient by ***Add New Patient*** (4. Icon) and fill the ID data for patient (at least the name)
9) Turn the unit on, it recognized the data communication process.
10) Download data from oximeter to PC, to open data in PC, double click at the file number in the left part of screen in window ***Records***
11) Delete the data after measurements by pressing the icon ***Delete patient data*** (6.icon)
12) Disconnect the pulse oximeter from PC and turn off the pulse oximeter and PC.

Troubleshooting:

Loss of pulse signal can occur in the following situations:

- The sensor is too tight
- There is an excessive illumination from light sources
- The patient has hypotension, severe vasoconstriction, severe anemia or hypothermia
- There is arterial occlusion proximal to the sensor
- The patient is in cardiac arrest or in shock
- A blood pressure cuff is inflated on the same extremity as the one with a SpO_2 sensor attached