
Pulse oximetry

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El pulsioxímetro es un instrumento de medida particularmente conveniente y no invasivo, muestra el porcentaje de sangre que es portadora de oxígeno. Más específicamente, muestra el porcentaje de hemoglobina arterial en la composición de la oxihemoglobina, (la proteína de la sangre que transporta el oxígeno). Los rangos normalmente aceptables para los pacientes sin patología pulmonar son del 95 al 99 por ciento. Para un paciente respirando aire ambiente, en alturas no muy por encima del nivel del mar, se puede hacer una buena estimación del nivel de pO₂ arterial con un monitor de "saturación de oxígeno" (SpO₂) suficientemente sensible. [2]

Un pulsioxímetro típico utiliza un microprocesador con un par de diodos emisores de luz (LED), enfrentados vis a vis con un fotodiodo, que envían unos trenes de impulsos que atraviesan una parte translúcida del cuerpo del paciente, puede-ser un dedo o un lóbulo de la oreja. Un LED tiene una longitud de onda de 660 nm (rojo) y el otro tiene una longitud de onda de 940 nm (infrarrojo).

La absorción de la luz de estas longitudes de onda difiere significativamente por parte de la sangre cargada de oxígeno y la sangre sin oxígeno:

La hemoglobina oxigenada absorbe más radiación infrarroja y permite pasar más luz roja - 660 nm
La hemoglobina desoxigenada absorbe más luz roja y permite pasar más radiación infrarroja - 940 nm.

Al arrancar el aparato, se crea un ciclo repetitivo en que los LEDs envían "una secuencia de impulsos" con una frecuencia de unas treinta veces por segundo: "primero un LED, luego el otro, después, ambos y entonces vuelve a empezar ", que permite que el fotodiodo detecte el nivel de luz roja y el nivel de luz infrarroja por separado y aparte se pueda ajustar el nivel de base de la luz ambiental. [3]

Se mide la cantidad de luz que atraviesa los tejidos (en otras palabras, la que no se absorbe) y se registran los niveles de señal normalizados separados para cada longitud de onda. Estas señales fluctúan en el tiempo ya que la cantidad de sangre arterial que está presente aumenta de golpe (literalmente: a trompicones como una ola) con cada latido del corazón, por lo que se sabe de forma segura que los máximos son de sangre arterial - la que se quiere medirse. Al sustraer el nivel mínimo de luz medido del nivel máximo medido para cada longitud de onda, se corrigen los efectos causados ??por los diferentes tejidos que han atravesado. [4]

A continuación se calcula la relación entre el nivel de luz roja y el nivel de luz infrarroja (que representa la proporción de la hemoglobina oxigenada respecto la hemoglobina desoxigenada), y esta relación es convertida por el procesador en un nivel de SpO₂ mediante una lookup table [4] obtenida de una forma empírica (por cada fabricante), aplicando la ley de Beer-Lambert, dado que la absorbancia de ambas hemoglobinas es la misma (punto isosbético) para las longitudes de onda de 590 nm y 805 nm. Los primeros pulsioxímetros empleaban estas longitudes de onda para la corrección de la concentración de hemoglobina. [3]

Principles of Pulse Oximetry Technology:

The principle of pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin. Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through. Deoxygenated (or reduced) hemoglobin absorbs more red light and allows more infrared light to pass through. Red light is in the 600-750 nm wavelength light band. Infrared light is in the 850-1000 nm wavelength light band.

Pulse oximetry uses a light emitter with red and infrared LEDs that shines through a reasonably translucent site with good blood flow. Typical adult/pediatric sites are the finger, toe, pinna (top) or lobe of the ear. 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.

There are two methods of sending light through the measuring site: transmission and reflectance. In the transmission method, as shown in the figure on the previous page, the emitter and photodetector are opposite of each other with the measuring site in-between. The light can then pass through the site. In the reflectance method, the emitter and photodetector are next to each other on top of the measuring site. The light bounces from the emitter to the detector across the site. The transmission method is the most common type used and for this discussion the transmission method will be implied.

After the transmitted red (R) and infrared (IR) signals pass through the measuring site and are received at the photodetector, the R/IR ratio is calculated. The R/IR is compared to a "look-up" table (made up of empirical formulas) that convert the ratio to an SpO₂ value. Most manufacturers have their own look-up tables based on calibration curves derived from healthy subjects at various SpO₂ levels. Typically a R/IR ratio of 0.5 equates to approximately 100% SpO₂, a ratio of 1.0 to approximately 82% SpO₂, while a ratio of 2.0 equates to 0% SpO₂.

The major change that occurred from the 8-wavelength Hewlett Packard oximeters of the '70s to the oximeters of today was the inclusion of arterial pulsation to differentiate the light absorption in the measuring site due to skin, tissue and venous blood from that of arterial blood.

At the measuring site there are constant light absorbers that are always present. They are skin, tissue, venous blood, and the arterial blood. However, with each heart beat the heart contracts and there is a surge of arterial blood, which momentarily increases arterial blood volume across the measuring site. This results in more light absorption during the surge. If light signals received at the photodetector are looked at 'as a waveform', there should be peaks with each heartbeat and troughs between heartbeats. If the light absorption at the trough (which should include all the constant absorbers) is subtracted from the light absorption at the peak then, in theory, the resultants are the absorption characteristics due to added volume of blood only; which is arterial. Since peaks occur with each heartbeat or pulse, the term "pulse oximetry" was coined. This solved many problems inherent to oximetry measurements in the past and is the method used today in conventional pulse oximetry.

Still, conventional pulse oximetry accuracy suffered greatly during motion and low perfusion and made it difficult to depend on when making medical decisions. Arterial blood gas tests have been and continue to be commonly used to supplement or validate pulse oximeter readings. The advent of "Next Generation" pulse oximetry technology has demonstrated significant improvement in the ability to read through motion and low perfusion; thus making pulse oximetry more dependable to base medical decisions on.

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A probe is placed on the finger, toe, ear lobe or nose. Two light-emitting diodes produce beams at red and infrared frequencies (660 nm and 940 nm, respectively). There is a photo detector on the other side. The diodes flash at approximately 30 times per second. The diodes are switched on in sequence, with a pause with both diodes off. This allows compensation for ambient light. The microprocessor analyses the changes in light absorption during the arterial pulsatile flow and ignores the non-pulsatile component of the signal (which results from the tissues and venous blood).

The oxygen saturation is estimated by measuring the transmission of light through the pulsatile tissue bed. This is based on the Beer-Lambert law:

Beer-Lambert law

This is a combination of two laws describing absorption of monochromatic light by a transparent substance through which it passes:

Beer's law: the intensity of transmitted light decreases exponentially as the concentration of the substance increases. August Beer, German Physicist (1825-1863)

Beer's Law is given by:

$$A = \ln(I_0/I)$$

Where:

A is the absorbance - how much light is absorbed while passing through the filter

I is the intensity of light transmitted

I_0 is the original intensity of light before passing through the filter

Lambert's law: the intensity of transmitted light decreases exponentially as the distance travelled through the substance increases. Johann Lambert, German Physicist (1728-1777).

The light absorbed by non-pulsatile tissues is constant (DC). The non-constant absorption (AC) is the result of pulsatile blood pulsations. The photo detector generates a voltage proportional to the transmitted light. The AC component of the wave accounts for between 1-5% of the total signal. The high frequency of the diodes allows the absorption to be calculated many times per second. This reduces movement effects on the signal.

The microprocessor analyses both the DC and AC components at 660 nm and 940 nm. The absorption of oxyhaemoglobin and deoxyhaemoglobin at these two wavelengths is very different. Hence, these two wavelengths provide good sensitivity.

Isobestic point

This is the point at which two substances absorb a certain wavelength of light to the same extent. In oximetry, the isobestic points of oxyhaemoglobin and deoxyhaemoglobin occur at 590 nm and 805 nm. These points may be used as reference points where light absorption is independent of the degree of saturation. Some earlier oximeters corrected for haemoglobin concentration using the wavelength at the isobestic points.

Thus comparison of absorbencies at different wavelengths allows estimation of the relative concentrations of HbO and Hb (i.e. saturation). Modern pulse oximeters may use two or more wavelengths, not necessarily including an isobestic point.

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