PULSE OXIMETRY by Nick Mark MD

onepagericu.com
@nickmmark
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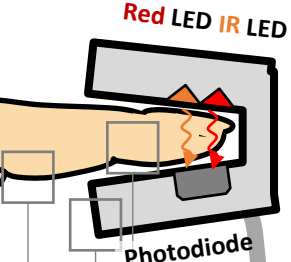
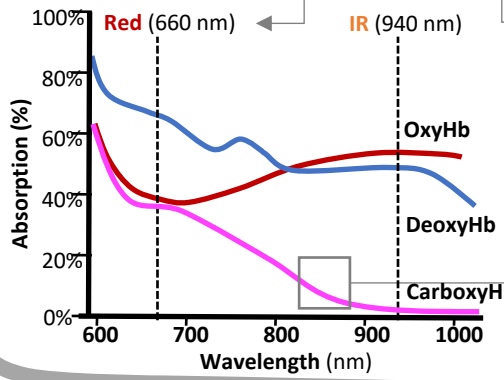
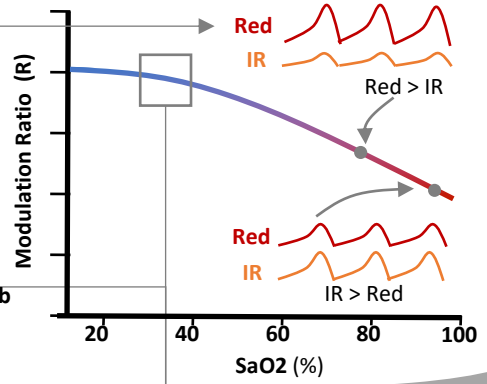
PRINCIPLE:
Pulse oximetry is the non-invasive continuous measurement of the oxygen saturation of hemoglobin. It exploits the fact that oxy- & deoxy hemoglobin differentially absorb red and infra-red light.

Shine Red and IR light through the skin and measure the absorption → ***DeoxyHb and OxyHb have different light absorption profiles*** → ***The signal that varies with time represents the pulsatile blood flow.*** → ***Using a standard curve, the ratio of Red/IR absorption (modulation ratio) is used to calculate the SaO2***







The **plethysomograph waveform** shows signal over time, corresponding to pulse

Amplitude may increase with greater SV (such as after a pause)

Perfusion index indicates the signal strength

PTT
Pulse transit time represents the interval from EKG R wave to PPG peak; determined by arterial compliance

Oxygen Saturation value (SpO2); value is calculated from the curve and averaged over 3-6 sec

ACCURACY OF PULSE OXIMETRY:

Several factors can affect the accuracy of pulse oximetry readings, including:

PROBE TYPE & POSITIONING

The pulse oximeter probe can be applied to different locations.

- **Finger** – most accurate; thumb may be more accurate than other fingers. Uses a transillumination method to measure.
- **Ears & Forehead** – slightly less accurate but may be more reliable in vasoconstricted states or hypothermia; uses backscatter method to measure.

No probe type is clearly superior; trial & error may identify the best probe type for an individual patient.

SKIN COLOR & NAIL POLISH

Pulse oximetry may overestimate SpO2 in dark skinned individuals (compared with SaO2 on ABG), particularly when patients are hypoxemic. Black patients are 3x more likely to have occult hypoxemia.

Fingernail polish may decrease the accuracy of pulse oximetry, particularly darker colors (blue, green, black, & brown)

LOW FLOW STATES

Low perfusion states (such as due to high vasoconstriction or low cardiac output) can make the pulse oximetry signal weak or even undetectable. This can make monitoring SpO2 difficult or impossible in patients with **non-pulsatile flow** such as patients on ECMO or with an LVAD.

ABNORMAL HEMOGLOBIN

- **Methemoglobinemia** (MetHb) causes a spurious reading, typically an SpO2 in the 85-88% range.
- **Carboxyhemoglobinemia** (CoHb) causes a false normal reading with SpO2 in the 94-100% range. Patients are hypoxic due to inability to unload O2 from Hb. (left shifted HbO2 curve)
- **Sulfhemoglobin** causes a spurious low SpO2 reading but patients may not be hypoxic (right shifted HbO2 curve)
- **HbA1c > 7** may cause overestimation of SpO2, though the effect is usually small.

Cooximetry can measure MetHb & COHb

LOWER ACCURACY AT LOW SPO2

Because the calibration curve was developed using healthy volunteers, measured SpO2 can differ from SaO2 significantly at low values (e.g. an SpO2 less than 75%).

HYPEROXEMIA

Hyperoxia is harmful (particularly after cardiac arrest) but pulse oximetry cannot differentiate normal from supra-normal PaO2 if the SpO2 is 100%. Target SpO2 ≥94%

PULSE OX LAG TIME

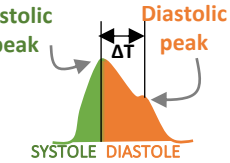
It takes time for blood to flow from heart to skin, as a result **pulse ox measurements lag by 5 – 15 seconds. Lag time** may be shorter if probe is placed more centrally on forehead/ears, & longer if cardiac output is low. This is why SpO2 may continue to drop a few seconds after successful intubation.

MEDICATION EFFECTS

Methylene blue, isosulfan blue, fluorescein, & indocyanine green can transiently cause falsely low SpO2 readings.

PLETHYSMOGRAPHY WAVEFORM ANALYSIS

The plethysmography waveform has systolic & diastolic components; examination can provide physiologic clues about vascular tone/compliance.

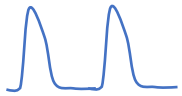


NORMAL

WEAK SIGNAL
- ↓↓ perfusion index
- try alternate positions/probes

VASOCONSTRICTED
- ↑ diastolic peak
- Shorter PTT, shorter ΔT
- ↓ perfusion index

VENOUS PULSATIONS (SEVERE TR)
- Late/prominent diastolic peak
- upsloping diastolic phase



VASODILATED
- ↑ systolic peak, ↓ diastolic peak
- Longer PTT, longer/undefined ΔT
- ↑ perfusion index

CO-OXIMETRY

Instead of the two wavelengths used by standard pulse oximeters, co-oximetry uses 4 wavelengths to accurately measure abnormal hemoglobins.