### PULSEOXIMETRY

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#### Introduction

• The maintenance of optimal O2 delivery is the core concern during anaesthesia

• "Oxygen lack not only stops the machine but wrecks the machinery"— J.S. Haldane.

• Monitoring of oxygenation using pulseoximeter avoids many catastrophies

#### **DEFINITION**

- Pulse oximetry, sometimes called the fifth vital sign, is a noninvasive method of measuring hemoglobin saturation (SpO<sub>2</sub>) by using a light signal transmitted through tissue
- A low SpO<sub>2</sub> can provide warning of hypoxemia before other signs such as cyanosis or a change in heart rate are observed

#### HISTORY

- MATHEES- father of oximetry
- 20 papers in1934 –1944
- HERTZMAN 1937 –use of photoelectric finger plethsmography
- 1975 –concept of pulse oximetry –Japan
- YELDERMAN &NEW -1983 –Nellcor pulse oximeter

#### Continuation...

• The American Society of Anesthesiologists (ASA) and American Association of Nurse Anesthetists have made assessment of oxygenation a standard for intraoperative and postoperative monitoring. In 2005, an audible alarm for the pulse oximeter was added to the ASA monitoring standard

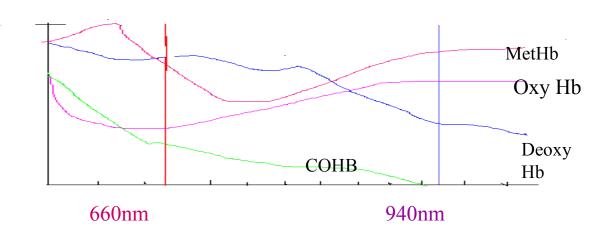
#### **PRINCIPLES**

- ABSORBTION SPECTRO PHOTOMETRY
- BEER LAMBERT LAW
- LAMBERT'S LAW states that when a light falls on a homogenous substance, intensity of transmitted light decreases as the distance through the substance increase
- BEER'S LAW states that when a light is transmitted through a clear substance with a dissolved solute, the intensity of transmitted light decreases as the concentration of the solute increases

#### CONTD...

- Substances have a specific pattern of absorbing specific wavelength –Extinction coefficient
- Uses two lights of wavelengths
- 660nm –deoxy Hb absorbs ten times as oxy hb
- 940 nm absorption of oxyHb is greater
- Lab oximeters use 4 wavelengths to measure 4 species of haemoglobin
- I<sub>t</sub>=I<sub>0</sub>e<sup>-Ecd</sup> [Ecd -absorbance]

Extinction coefficient



wavelength

#### DESIGN OF PULSEOXIMETER

#### • 2 WAVELENGTHS-

660nm [red] & 940nm[infra red]

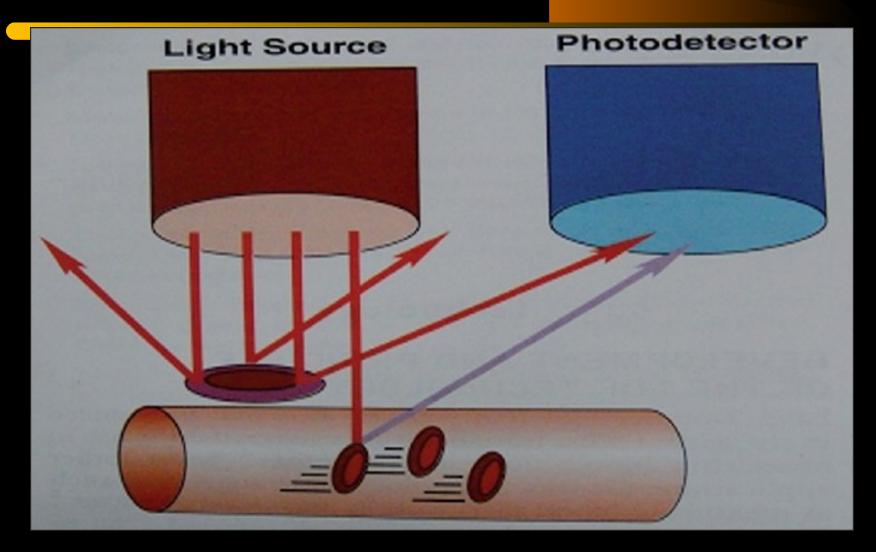
The ratio of absorbencies at these two wavelengths is calibrated empirically against direct measurements of arterial blood oxygen saturation ( $S_aO_2$ ) in volunteers, and the resulting calibration algorithm is stored in a digital microprocessor within the pulse oximeter.

- LED & PHOTODETECTOR
- Newer types of LED is based on aluminium gallium arsenide system
- Signal processed in the micro processor
- Senses only the pulsatile flow

## Operating principles

• The pulse oximeter estimates SpO<sub>2</sub> from the differential absorption of red and infrared light in tissue. Reduced hemoglobin absorbs more light in the red band than oxyhemoglobin .Oxyhemoglobin absorbs more light in the infrared band.

# reflectance pulseoxymetry



#### Continuation....

- Reflectance oximetry relies on light that is reflected (backscattered) to determine oxygen saturation
- Reflection originates from nonhomogeneity in the optical path, that is, at the interfaces between materials with different reflective indices





# Oxygen desaturation

- Saturation is defined as ratio of O2 content to oxygen capacity of Hb expressed as a percentage.
- Desaturation leads to Hypoxemia a relative deficiency of O2 in arterial blood.
   PaO2 < 80mmHg – hypoxemia</li>

#### CONTD...

- Oxygen saturation will not decrease until PaO2 is below 85mmHg.
- At SaO2 of 90% PaO2 is already 60mmHg.
- Rough guide for PaO2 between saturation of 90%-75% is PaO2 = SaO2 30.
- SaO2< than 76% is life threatening.

#### Fractional Saturation

• This is Ratio of oxygenated Haemoglobin to sum of all haemoglobin in blood.

Fractional saturation = HbO2

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HbO2+ Hb+ Met Hb +CO Hb

#### **Functional Saturation**

• This is a measure of ratio between HbO2 and sum of oxygenated and reduced Hb.

• Functional Saturation= HbO2

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HbO2 + Hb

#### Types of Hypoxemia

- 1. Hypoxic hypoxemia
- ↓ PaO2 ↓ SaO2 Normal Hb

2. Anaemic hypoxemia

\$\delta\$Hb, Normal PaO2 & SaO2

3.Toxic hypoxemia ↓SaO2,Normal PaO2

PaO2 [mmHg]

SaO2 [%]

Normal

97 to ≥80

97 to  $\ge$ 95

Hypoxia

< 80

< 95

Mild

60-79

90-94

Moderate

40 - 59

75 - 89

Severe

<40

< 75

# physiology

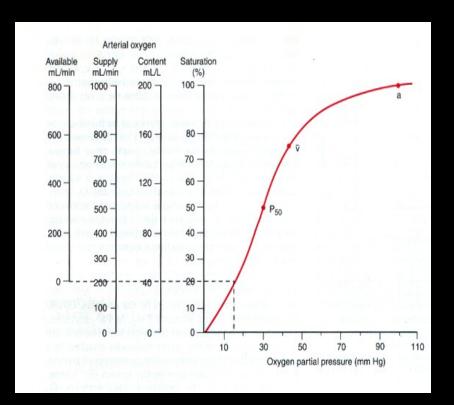
• Efficient oxygen transport relies on the ability of hemoglobin to reversibly load and unload oxygen. The relationship between oxygen tension and oxygen binding is seen in the oxyhemoglobin dissociation curve which plots the hemoglobin oxygen saturation against the oxygen tension.

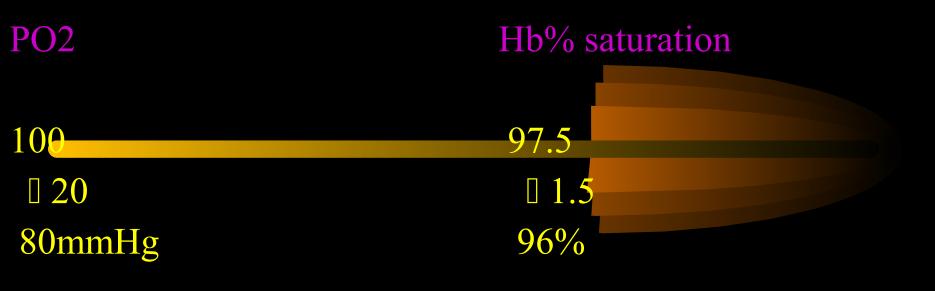
# Relationship between PaO2 and SaO2

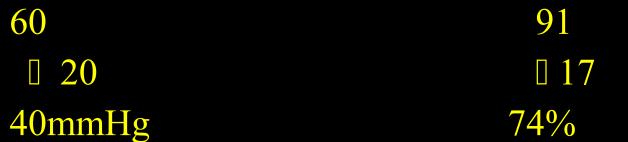
Oxygen – haemoglobin dissociation curve

The sigmoid shape of the curve is essential for

physiologic transport







# Cardiovascular response to hypoxemia

SPO2%	HR	BP	Stroke volume	SVR	Response
>80				No change	Reflex
60-80			No change		Direct
<60					Direct

# Uses of pulseoximetry

- Monitoring oxygenation
  - During anaesthesia
  - in ICU, PACU
  - during transport
- Monitoring oxygen therapy
- Assesment of perfusion
- Monitoring vascular volume
- Sleep studies -24-h ambulatory recordings of SpO2 is useful for screening for daytime sleep sequelae associated with the potential risk of this pathology in OSAS during social activities.

#### Continu...

- Emergency department
- Reflectance pulse oximeters can be useful for assessing fetal status during labor and delivery by applying a forehead probe

#### Continuatio...

• Pulse oximetry has been used during cardiopulmonary resuscitation .Because of artifacts and lag times, it is more useful in primary respiratory arrest than in cardiac arrest. It is useful in assessing oxygenation during newborn resuscitation

Out-of-hospital Use
 Pulse oximetry is useful in the prehospital setting, including when transporting patients by helicopter or ambulance
 Controlling Oxygen Administration

# Monitoring Peripheral Circulation

• Pulse oximetry can detect arm positions that compromise circulation. The pulse oximeter that is attached to a toe can help to warn of decreased perfusion at the foot in patients in the lithotomy position

#### Contin...

- Locating Arteries:
- Determining Systolic Blood Pressure
- Avoiding Hyperoxemia
- Monitoring Vascular Volume and Sympathetic Tone

# Advantages

- Simple to use
- Non-invasive
- Require no warm up time
- Especially in African & Asian patients
- Cost-effectiveness over ABG

- Accuracy
- Independence from Gases and Vapors
- Fast Response Time
- Continuous Measurements
- Separate Respiratory and Circulatory Variables
- Convenience

- Fast Start Time
- Tone Modulation
- User-friendliness
- Light Weight and Compactness
- Probe Variety
- Battery Operated

## Disadvantages

Decrease in PAO<sub>2</sub> before fall in SPO<sub>2</sub>

Due to the shape of ODC

>SPO<sub>2</sub>94% - PAO<sub>2</sub> 75%

#### Continuat...

- Difficulty in Detecting High Oxygen Partial Pressures
- Erratic Performance with Dysrhythmias

### Limitations

- Shivering patient -motion artefacts
- High intensity ambient light
- Perfusion of the patient ear probe may be more reliable
- **Abnormal pulses** –erratic perfomance
- **Penumbra effect** 
  - light shunted directly to photo dectector

### Contd...

Carboxy Hb – Produces  $SpO_2 > than true O_2$  saturation

10-20% in heavy smokers

At 660nm its absorbtion similar to oxyhaemoglobin ,so over reads

For every 1%COHB 1% increase in pulseoximeter reading

Methaemoglobinemia – absorbs equal amount of red &infra red light - Cause SpO<sub>2</sub> to move towards 85%

CONTD....

- ✓ Endo / exogenous dyes interfere
  - -Indocyanine green, indigocarmine, methylene blue
- ✓ Blue ,Black ,Green nail polishes
- ✓ Diathermy leads to disturbance in monitor
  - can be corrected by placing grounding plate near surgical field probe as far away from surgical field

& electro cautery

## Problems

- False positives and negatives
- Burn injury
- Pressure injuries

# Other types of oximetry

Reflectance oximetry
 sense back scattered light
 LED placed to the side of photo diode
 Dis adv - noise interference & more costly
 Adv - signal in low perfusion is better

### Contd...

- ☐ Masimo signal extraction technology
- ☐ Mixed venous blood o2 saturation
  - by special PAC
- ☐ Noninvasive brain oximetry
  - senses regional o2 saturation in brain[rSO2]
  - sensor in forehead emits light of specific wavelength & measure the reflected light
- ☐ Transcutaneous oximetry

## Sites

- Finger
- Toe
- Ear lobe
- Nose
- Tongue
- Cheek
- esophagus

### Other sites

• Pharyngeal pulse oximetry by using a pulse oximeter attached to a laryngeal mask may be useful in patients with poor peripheral perfusion

### continua

• Flexible probes may work through the palm, foot, penis, ankle, lower calf, or even the arm in infants

### Contin...

 Pulse oximetry may be used to monitor fetal oxygenation during labor by attaching a reflectance pulse oximetry probe to the presenting part A disadvantage is that the probe has to be placed blindly and may be positioned over a subcutaneous vein or artery, which will affect the reliability of the readings.

## fixation

- Proper probe placement is crucial for good performance. A malpositioned probe can result in false-positive and false-negative alarms
- The probe should be protected from bright light

## Patient Complications

- Corneal Abrasions
- Pressure and Ischemic Injuries
- Burns
- Electric Shock
- Carbon Monoxide Monitoring

## Oxymetry standards

- There must be a means to limit the duration of continuous operation at temperatures above 41°C.
- The accuracy must be stated over the range of 70% to 100% SpO<sub>2</sub>. If the manufacturer claims accuracy below 65%, the accuracy must be stated over the additional range.

### Continu...

- If the manufacturer claims accuracy during motion, this and the test methods used to establish it must be disclosed in the instructions for use.
- If the manufacturer claims accuracy during conditions of low perfusion, this and the test methods used to establish it must be disclosed in the instructions for use.

### Continuatio...

- There must be an indication when the SpO<sub>2</sub> or pulse rate data is not current.
- An indication of signal inadequacy must be provided if the SpO<sub>2</sub> or pulse rate value displayed is potentially incorrect

### Continuation...

• If the pulse oximeter is provided with any physiologic alarm, it must be provided with an alarm system that monitors for equipment faults, and there must be an alarm for low SpO<sub>2</sub> that is not less than 85% SpO<sub>2</sub> in the manufacturer-configured alarm preset. An alarm for high SpO<sub>2</sub> is optional.

## Take home message

- Remember at SaO<sub>2</sub> of 90%, PaO<sub>2</sub> is already 60mmHg
- SaO2 < than 76% is life threatening



# Case Study

- Consider Mrs. W., a patient scheduled to undergo an endoscopy. A complete blood count (CBC) shows her total hemoglobin level is normal 15 mg/dl. A pulse oximeter shows that her oxygen saturation level is 97%.
- To determine her overall oxygen-carrying capacity, multiply 1.34 ml (the amount of oxygen each gram of hemoglobin carries) by the hemoglobin level and then by the  $SpO_2$ . 1.34 x 15 x 0.97.
- The total amount of oxygen carried in Mrs. W.'s hemoglobin is 19.50 ml/dl (hemoglobin oxygen content), which falls within the normal range of 19-20 ml/dl.

#### Contd...

- Mr. B., who's had shortness of breath for two days. His lungs are clear, and although he has not specific pulmonary symptoms, he looks malnourished and is anaemic.
- A spot check with a pulse oximeter shows a SpO<sub>2</sub> of 97%, the same as Mrs. W., you discover that Mr. B.'s hemoglobin oxygen content is 14.30 ml/dl, far below normal values.
- Because Mr. B. has fewer hemoglobin molecules, the total amount of oxygen available to his tissues is low, resulting in shortness of breath. What hemoglobin he does have is full of oxygen, producing normal and misleading SpO<sub>2</sub>.

• These two cases illustrate a major cautionary note: Never let normal SpO<sub>2</sub> readings lull you into a false sense of security! Always interpret SpO<sub>2</sub> values in the context of the patient's total hemoglobin level.

