Pulse Oximetry

- Oximetry is measuring how much oxygen the blood is carrying, the oxygen saturation of the blood.
- This is a very useful thing for clinicians to know, especially in patients with respiratory disorders:
  - Oxygen is the most acutely necessary substrate for aerobic life.

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- Oximetry is measuring how much oxygen the blood is carrying, the oxygen saturation of the blood.
- This is a very useful thing for clinicians to know, especially in patients with respiratory disorders:
  - Oxygen is the most acutely necessary substrate for aerobic life.
  - Insufficiency of oxygen (hypoxia) leads to devastating neurological handicaps, if not death.

Pulse Oximetry

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"The pulse oximeter is arguably the most significant technological advance ever made in monitoring the well-being and safety of patients during anaesthesia, recovery and critical care"

Severinghaus & Astrup (1986)
Measuring SaO₂

- Is it possible to measure arterial SaO₂ without taking a blood sample?
- It is the haemoglobin molecule which carries oxygen.
- It is the haemoglobin molecule which gives blood its distinctive colour.
- The two forms of the molecule (Hb and HbO₂) have different absorption spectra.

There is a window of opportunity here:
- The wavelength range between 600 and 1,000 nm is also the range for which there is the least attenuation of light by body tissues.
- By measuring the light transmission through a body segment at two wavelengths within that range, the arterial SaO₂ can be determined.

Oximetry is a non-invasive optical technique

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Optical Sensors

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  - Inherent safety
  - Immunity to electrical interference
  - No reference electrode required
  - Optical sensing techniques can be envisaged for most analytes

A simple model for oximetry

Assume that the transmission of light through the arterial bed depends only on the path length, the relative concentrations of Hb and HbO₂ and their absorption at the two wavelengths λ₁ and λ₂. Let:

- $C_0$ = concentration of oxyhaemoglobin (HbO₂)
- $C_r$ = concentration of reduced haemoglobin (Hb)
- $\mu_{a,1}$ = absorption coefficient of HbO₂ at wavelength $\lambda_1$
- $\mu_{a,2}$ = absorption coefficient of Hb and wavelength $\lambda_2$
A brief history of oximetry

- Matthys, 1935
  - Transillumination of the earlobe at two wavelengths.
- Goldie, 1942
  - Compression of earlobe to obtain "bloodless" reference.

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  - No differentiation between arterial, venous and capillary blood.
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- Merrick and Hayes, 1976
  - Hewlett-Packard multi-wavelength oximeter.

Hewlett–Packard Ear Oximeter

- Basic Principles:
  - Multi-component model of ear pinna.
  - Each light absorber assumed to act independently of the others.
  - Measurement of light transmission at 8 wavelengths between 650 and 1050 nm.
  - Empirical calibration coefficients derived from study on 22 volunteers (750 data points).

- Disadvantages:
  - Complex instrumentation and signal processing.
  - Need for pre-calibration.

¹ The pinna, or auricle, is the outer projecting portion of the ear.
Hewlett-Packard Ear Oximeter

- Disadvantages:
  - Complex instrumentation and signal processing.
  - Need for pre-calibration.
  - Ear must be heated to 41°C for arterIALIZation of capillary blood.

Problems with oximetry

- The need to distinguish between absorption due to arterial blood (the wanted signal) and the absorption due to other components requires either:
  - An unacceptable procedure.
  - A complex model and an even more complex instrument.

  The solution?
  Pulse oximetry

Pulse Oximetry

- Discovered in Japan in the mid-1970's (Aoyagi, 1974)

- Only that part of the signal directly related to the inflow of arterial blood into the body segment is used for the calculation of SaO₂.

- If $R$ is redefined as follows:

  $R = \frac{\log_{10} \frac{I_{p0}}{I_{p1}}}{\log_{10} \frac{I_{d0}}{I_{d1}}}$

  where $I_{p0}$ and $I_{p1}$ are the transmitted intensities without and with the pulse, respectively, and $I_{d0}$ and $I_{d1}$ are the transmitted intensities without and with the pulse, respectively.
Pulse Oximetry

- If $R$ is redefined as follows:
  \[ R = \frac{\log_{10} I_{a}}{\log_{10} I_{b}} \]
- Then the oximetry equation we derived earlier still holds:
  \[ S_{AO_2} = \frac{\alpha_{o_2} - \alpha_{o_1}}{\alpha_{o_2} - \alpha_{o_1}} \]
  where $\alpha_{o_i}$ is the absorption coefficient of Hb at wavelength $\lambda_i$.

Calibration

- Empirical studies show that the actual relationship between $R$ and oxygen saturation is as follows:

Any volunteers?