1.1 Pulse Oximeters

Because of their ease of use, pulse Oximeters are extremely popular and have become one of the first measurements attempted in any critical medical situation from the scene of event to postoperative care, and even home care. They have been proven to be reliable and accurate in the indication of SpO_2 within the range 80-100%.

1.2 How Pulse Oximeters work

It is not the intention here to describe in detail the theory and practice of pulse oximetry in any depth, this has been exhaustively covered by others. To attempt to explain in simple easily understood terms the basics. The user is advised to seek detailed explanations from published works and the individual manufacturers and not to use this section as an absolute reference.

The principles behind SpO_2 are very simple, the colour of blood changes depending on the oxygen saturation of the haemoglobin. As the haemoglobin loses Oxygen the skin colour changes from pink, taking on a blue tint.

The technique of SpO_2 monitoring depends on the principal that haemoglobin and oxyhaemoglobin absorb different amounts of light. The amount absorbed varies as a function of the wavelength (colour). The amount of blue is determined by the saturation of Oxyhaemoglobin relatively has limited effect over the range 600 nm to 1000 nm compared to the haemoglobin it needs to be remembered that the extinction curves are logarithmic.

Figure (A) Diagram of curve.

If two specific wavelengths are used e.g. Red at 660 nm and I.R. at 900 nm. The 900 nm wavelength is partially absorbed by both the oxyhaemoglobin and its reduced counterpart the haemoglobin. By contrast, the absorption of the 600 nm wavelength is largely due to the reduced haemoglobin.

Pulse Oximeters have to differentiate between light absorption due to arterial blood and that due to other fluids and soft issues. Arterial blood pulsates whilst most of the other components remain stationary. The change in volume of the arterial pulse during the cardiac cycle alters the optical path and therefore outputs and A.C. signal. It is then possible for the software to calculate from this signal the SpO_2 values.

Most current pulse Oximeters measure the ratio of the absorption of light by two principal forms, haemoglobin and saturated arterial haemoglobin (often referred to as oxyhaemoglobin and represented as $Hb0_2$/SAT, and unsaturated (or reduced) haemoglobin Hb).
The oxygen saturation SpO_2 is defined as the ratio of the concentration of oxyhaemoglobin to reduced haemoglobin. Oxygen saturation is commonly expressed as a percentage and is calculated according to the manufacturers specific formulae.

The L.E.D.'s used in pulse Oximetry need to emit sufficient power to travel through heavily pigmented tissue and yet still function without a system overload when a thin lightly pigmented area is used. The output of L.E.D.'s is approximately linear in relation to the drive currents used so pulse oximeters are designed to be able to automatically control their outputs to match the physical conditions encountered.

A wide band photo diode detector is used as it has a large dynamic range for detecting wavelengths in the visible and I.R. electromagnetic spectrum. However they are unable to differentiate between the wavelengths so alternating Red and I.R. is used so that the oximeter always knows which wavelength it is looking at.

Pulse Oximetry in general is not absolute, but has questionable accuracy due to problems with interference from ambient light and patient movement. Thus calibration is difficult;

Figure (B) Diagram of finger probe.

Figure (C) Diagram of pulsetile waveform.

The elimination of the effects of absorption which is caused by the presence of venous and capillary blood, soft tissue and ambient light changes are part of the manufacturers software. The pulse Oximeter software calculates the AC component of both wavelengths and divides this by the corresponding DC (amplitude) component.
The 'R' ratio is then derived from the formulae :-

$$(AC_{660} / DC_{660}) / (AC_{900} / DC_{900})$$

When the ratio equals 1.00, the oxygen saturation is approximately 85%.