Introduction

Within the last 40 years many attempts have been made to measure the arterial oxygen saturation \( \left( S_{aO_2} \right) \). The arterial oxygen saturation is defined as the amount of oxyhaemoglobin \( (HbO_2) \) expressed as a percentage or as a fraction of the amount of total haemoglobin \( (THb) \) including haemoglobin \( (Hb) \) plus carboxyhaemoglobin \( (HbCO) \), oxyhaemoglobin \( (HbO_2) \) and methaemoglobin \( (MetHB) \) under physiological as well as clinical conditions.

The use of ear oximetry was first described in 1935 but was not generally accepted into clinical practice until very recently because of difficulties in calibration and doubts about the accuracy of the available instruments. However, marked improvements in instrumentation brought the technique into use in clinical work and research. The technique of pulse oximetry consists of the measurement of light transmission through the ear lobe or the fingertip and is analogous to spectrophotometry, using a cuvette for blood oxygen measurements. Oximetry now has defined applications in monitoring the effects of therapeutic manoeuvres, in intensive care units, during artificial ventilation, exercise studies, bronchoscopy and sleep studies, and in anaesthesia. Changes in \( S_{aO_2} \) can be continuously measured, which is difficult to achieve with invasive techniques. Blood gas analysis is routinely used in clinical practice to measure pH, \( P_{CO_2} \) and \( P_O_2 \) directly, but other values are calculated and cannot by themselves be accepted as accurate monitoring systems. The purpose of pulse oximetry, therefore, is to measure the arterial oxygen saturation continuously and non-invasively in the peripheral circulation (ear lobe or fingertip). However, efforts to achieve accurate results have been affected by low blood flow or low pulse volume, by \( HbCO \) and \( MetHB \), and by light scattering and reflection, not only by the blood itself but also by the tissues.

On this basis we examined three questions in our study:

1. Does the peripheral blood flow influence the pulse oximeter measurement?
2. Does an altered blood composition, especially the presence of HbCO and MetHb, have any influence?

3. What is the correlation between the non-invasive pulse oximeter $S_pO_2$ values and those taken from arterial blood samples?

We also paid attention to basic problems like the oxygen status of arterial blood and its diagnosis ($P_{O_2}$, $S_aO_2$ and $C_aO_2$) and the determination and clinical relevance of those variables.

**Materials and Methods**

The Biox pulse oximeter measures saturation non-invasively and continuously in the peripheral circulation (ear lobe or fingertip) using two wavelengths. A small, lightweight ear probe contains the light sources and detector. The probes contain a built-in heater to maintain skin temperature within a range of 36°–38°C. The Biox III $S_pO_2$ and heart rate outputs were recorded (Linseis) continuously. Heart rate was also recorded using a fingertip system and the ECG (Siemens Sirecust). Blood pressure was recorded frequently using the Critikon Dynamap. In patients undergoing artificial ventilation we routinely used a capnolog ($P_{Eco_2}$) and an oxychek for analysing the end-tidal $P_{CO_2}$ and the inspiratory $O_2$ ($FiO_2$). Ventilation was controlled by the Dräger-Barolog from which the ventilation frequencies (min⁻¹) and the inspiratory pressures ($P_{BI}$; mbar) were recorded together with a Precom system (Dräger).

To obtain arterial blood samples a Vygonflon T 22-G long-term assessment arterial cannula was placed in a radial artery after Allen’s test was done. $HbO_2$ in arterial blood was measured with the CO-oximeter 2500 (Corning). $S_aO_2$ (calc) was also obtained from the blood gas analysis using an ABL II (Radiometer). The Corning 2500 measures THb, $HbO_2$, $HbCO$, MetHb and deoxyhaemoglobin percentages and calculates oxygen content (synonym, oxygen concentration; $C_aO_2$) in the blood. The accuracy and reliability of this CO-oximeter have been well documented. The CO-oximeter was checked and calibrated at daily intervals with the Corning Standard and certain dyes. A reference standard, the slope Hb, suggested by the manufacturer, was used twice a day. The accuracy was also checked daily with the zero calibration together with three known Hb solutions. The Radiometer blood gas analyser was checked daily.

The Biox III was allowed a 5-min warm-up period before use. It was then placed in the Test mode to verify correct processor circuit and probe operation before use (the Biox III is calibrated and standardised by the factory and therefore requires no further calibration before use). The patient's ear lobe was made hyperaemic either by vigorously rubbing the ear lobe between thumb and forefinger with an isopropyl alcohol pad for approximately 30 s or by using a special ointment (Finalgon). The ear probe was then placed on the patient and a stable baseline value was displayed within 3 min. If the ear lobe was insufficiently vascularised for an accurate reading, a Probe Low alarm signalled an alert. In the absence of such an alarm the operator used a crystalline heparinised gas-tight syringe (Braun, Melsungen) to obtain a blood sample of at least 2 ml through the arterial cannula.