A new Micro Device for Non-Invasive Determination of Local Blood Oxygen Saturation Based on Tissue Remission Spectra

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Abstract

The determination of local blood oxygen saturation is considered to be one of the most important tasks in medical diagnostics. Although, for the non-invasive measurement of global blood oxygen saturation, several easy to use devices, so called "pulsoxymeter", are commercially available, local blood oxygenation determination is still a technological problem.

1 Motivation

Determination of the global blood oxygen saturation is known for a long time and several easy to use devices are commercial available. Nevertheless the determination of the local blood oxygen saturation is still a challenge.
The local blood oxygen saturation is a very important parameter in plastic surgery, graft and wound control, detection of carcinoma, ophthalmology and many more medical tasks. Up to now only a few instruments are capable to perform this measurements [1,2]. Because of their size these instruments are only for stationary use. The evaluation of blood oxygen saturation and of haemoglobin concentration is not very reliable.
In this paper a new handheld micro optical device is presented which shows an important progress in local blood oxygen saturation and haemoglobin concentration measurements [3]. Measurements on an ischaemia show the reduced blood supply.

2 Theoretical Background

All human cells need oxygen. Only if enough oxygen is available the mitochondria can produce energy. Just a small amount of oxygen is directly diluted in the blood (< 1%). The rest accumulates at the protein haemoglobin. Therefor the oxygen saturation of the haemoglobin is a direct hind for the oxygen supply of the cells. The functional oxygen saturation SO_2 is determined as the relation between oxygenated haemoglobin and the sum of oxygenated and deoxygenated haemoglobin :

$$SO_2 = \frac{c_{HbO_2}}{c_{Hb}+c_{HbO_2}}$$

For determination of the local blood oxygen saturation a full spectrum between 500 and 600 nm is investigated. The spectra for fully oxygenated (SO_2=100%) and deoxygenated (SO_2=0%) haemoglobin displayed in Fig.1 show significant differences. Due to this every blood oxygen saturation can be displayed as a superposition of these spectra. This allows the exact determination of the local oxygen blood saturation.

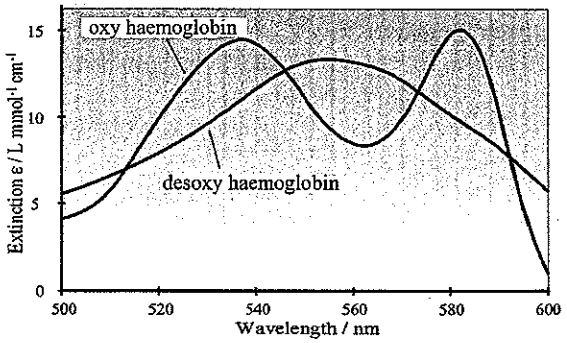

Fig. 1: spectra for fully oxygenated and completely deoxygenated haemoglobin

3 The Micro-Spectrometer

The experimental set up is shown in Fig. 2. The light of a white LED (Nichia NSPW 300BS) is focused into a bundle of six optical fibres which guide the

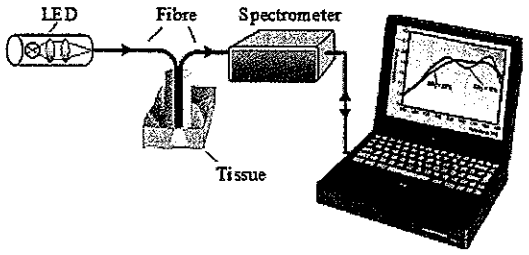

Fig. 2: sketch of the micro-spectrometer

light into the region under investigation, a signal fibre collects the remitted light out of the tissue into a miniature spectrometer (CP 20 Jobin Yvon). A 14-Bit line camera digitise the spectrum an transfers it to a computer. 100 spectra per second can be recorded.

4 Data-Evaluation

The main challenge in data-evaluation is modelling the propagation of light in tissue [4]. Due to multiple scattering of photons at cellular structures solving the Maxwell-equations becomes impossible. It is necessary to use heuristic theories like Monte Carlo simulations or Kubelka-Munk. One of the standard methods for determination of blood oxygen saturation and relative haemoglobin concentration is the Kubelka-Munk formalism [5]. This model is a pure scattering theory. It uses large simplifications for the optical parameters, which shows the reality only limited. A new approach the so called FIR method (FIR: Finite Impulse Response) uses a Taylor expansion of a likelihood consideration. For the determination of blood oxygen saturation and relative haemoglobin concentration FIR-filter coefficients are used.

5 Measurements

As a first test an ischaemia with subsequent hyperaemie was measured. The measurement displayed in Fig. 3 was performed in the following way. For 60 seconds the remission spectra of a finger where taken subsequently a tourniquet was closed and opened again after 300 seconds. Measurements where taken every second. Each spectrum was averaged over 150 ms. The blood oxygen saturation and the haemoglobin concentration where evaluated. The decline of blood oxygen saturation during the time using the tourniquet can clearly be seen. The haemoglobin concentration shows that during the closing procedure more blood is pressed into the finger. A second peak in the haemoglobin concentration after 360 seconds show the reactive hyperaemia due to the fact that the tourniquet was opened again.

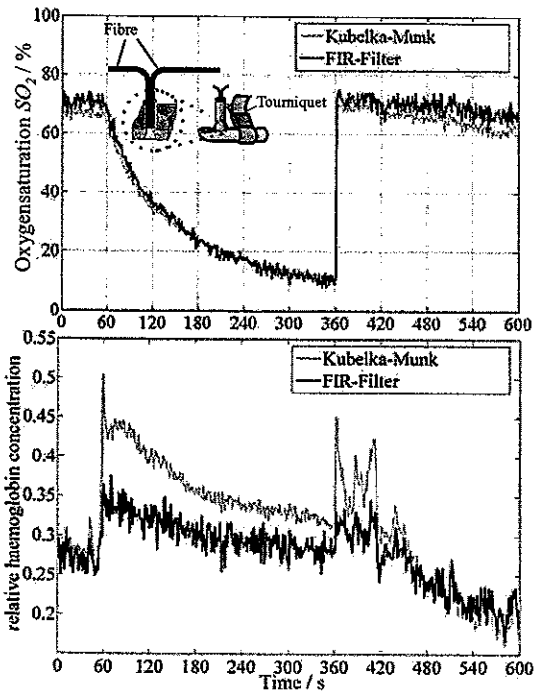

Fig. 3: upper image: oxygen saturation; lower image: relative haemoglobin concentration

6 Conclusions

The micro measuring system represented here, can be used for measuring tasks in medical diagnostics. Fields of application would be e. g. in plastic surgery, transplant and wound control, and many more.
With this optical micro measuring system and with a clearly improved evaluation method for tissue remission spectra (FIR-filtermethod) new possibilities for non invasive determination of local blood oxygen saturation and relative haemoglobin concentration are given.

7 Literature

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