9.

PRELIMINARY RESULTS OF OXYGEN SATURATION WITH A PROTOTYPE OF CONTINUOUS WAVE LASER OXIMETER

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1. INTRODUCTION

The state of oxygenation of biological tissues is measured by the oxygen saturation (Y) defined as the percentage of oxy-hemoglobin with respect to the total hemoglobin concentration. The oximetry techniques currently in use can be divided into two categories: invasive methods, that require the use of catheters, or provide in-vitro analysis of a blood or tissue sample and non-invasive methods such as the gas-transcutaneous oximetry and the pulse oximetry[1,2,3]. The gas-transcutaneous oximetry uses a Clark electrode to measure the weak current which is related to the partial pressure of oxygen in the underlying capillaries. Although this method is widely used, it presents many disadvantages: the measurement is indirect, it is limited to the subclavicular or dorsalis pedis area, where perfusion is more consistent, and the result of the analysis is strongly affected by numerous parameters, which are difficult to control, such as the room temperature and humidity. Moreover it does not permit long lasting detection.

Near-infrared spectroscopy provides a non-invasive, real time measurement of the tissue optical parameters (absorption coefficient μ_a and reduced scattering coefficient μ'_s), which allows the calculation of the concentrations of oxy-, deoxy- and total hemoglobin in tissues[4,5].

The pulse oximetry is an optical technique which exploits the measurement of near infrared (NIR) radiation transmitted by the tissue and can therefore only be used to monitor thin layers of tissue such as earlobe or fingertips[1,3].

Moreover, different NIR optical techniques exist, namely time-resolved, phase-resolved and continuous wave (CW) oximetry, which measure Y by detecting the radiation backscattered by the tissue and can be applied to any part of the body giving

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readings independent of external conditions[5] (temperature and humidity). Although time- and phase-resolved optical oximetry give very precise *Y* estimation, CW oximetry, which gives a fairly accurate estimation of *Y*, has the advantage to be a low-cost technique which can be implemented in a non cumbersome instrument.

We developed a prototype of quasi-CW tissue oximeter employing two laser diodes at 750 and 810 nm. The radiation is delivered to the tissue by means of two plastic optical fibres and the backscattered radiation is collected using four plastic optical fibres and detected by a large-area silicon photodiode.

2. THEORY

As known, optical spectroscopy in the NIR region, ranging from 700 to 900 nm, achieves sufficient photon penetration depth for non invasive probing of macroscopic tissue volume[6].

The light propagation in biological tissue is governed mainly by absorption and diffusion mechanisms. The latter must be ascribed to the local mismatches in the index of refraction that occur in correspondence to membrane interfaces or to organelles and particles that act as diffusion centres. In biological tissues this process is anisotropic, so that in a single event, photons are scattered preferentially in the forward direction[3,5,7].

In the NIR region of the spectrum the only species that consistently contribute to absorption are water, hemoglobin, and lipids; in particular in the wavelength range between 700 and 900 nm, the absorption is mostly due to oxy- and deoxy-hemoglobin[8].

Thus, at two near-infrared wavelengths λ_1 and λ_2, the absorption coefficient can be written in terms of the Lambert-Beer relationship

$$\mu_a(\lambda_1) = \varepsilon_{Hb}(\lambda_1)[Hb] + \varepsilon_{HbO_2}(\lambda_1)[HbO_2] \tag{1}$$

$$\mu_a(\lambda_2) = \varepsilon_{Hb}(\lambda_2)[Hb] + \varepsilon_{HbO_2}(\lambda_2)[HbO_2] \tag{2}$$

where ε_{Hb} (ε_{HbO2}) and [Hb] ([HbO_2]) are the extinction coefficient and tissue concentration of deoxy- (oxy-) form of hemoglobin, respectively.

The ratio of absorption coefficients can be written as

$$\frac{\mu_a(\lambda_1)}{\mu_a(\lambda_2)} = \frac{\varepsilon_{Hb}(\lambda_1) + Y\left[\varepsilon_{HbO_2}(\lambda_1) - \varepsilon_{Hb}(\lambda_1)\right]}{\varepsilon_{Hb}(\lambda_2) + Y\left[\varepsilon_{HbO_2}(\lambda_2) - \varepsilon_{Hb}(\lambda_2)\right]} \tag{3}$$

where

$$Y = \frac{[HbO_2]}{[Hb] + [HbO_2]}$$

is the oxygen saturation.

Furthermore, if λ_2 is the isosbestic wavelength of hemoglobin (810 nm), which is the wavelength at which the extinction coefficients of oxy- and deoxyhemoglobin are equal, the saturation *Y* can be written as