Development of a Near-Infreared Sensor to assess Myocardial Ischemia

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Introduction

Monitoring myocardial oxygenation is important when performing surgical interventions. However, in clinical routine only indirect surrogate parameters of ischemia, such as wall motion abnormalities, can be detected when imaging tools like echocardiography are used. However, wall motion abnormalities occur late in the ischemia cascade. Therefore, earlier detection of myocardial ischemia could make surgical intervention safer. Oxygen is transported by hemoglobin and myoglobin. These molecules have specific light absorption in the Near-Infrared spectrum [1]. By integrating a Near-Infrared Spectroscopy (NIRS) sensor to a trans-esophageal echocardiogram (TEE) probe, ischemia in the left ventricle could be detected. This work presents the prototype developed to measure oxygen saturation of the myocardial tissue.

Materials and Methods

The shape of the prototype was designed to be wrapped around the TEE probe. LED wavelengths were selected wisely to optimize oxygen saturation measurements. As light follow a banana-shaped pathlength between source and detector, photosensors were placed at several distances to reach different tissue depths.

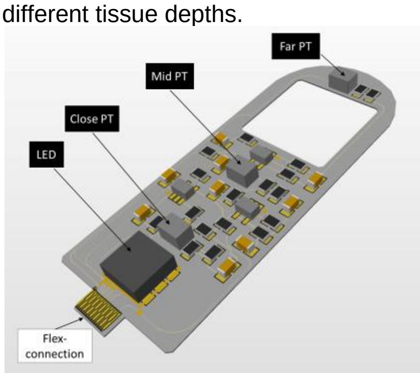

Fig. 1 Flexible circuit of the NIRS sensor system. Multichip LED and phototransistors (PT) are shown. Close, Mid, and Far PT were placed at 3, 15 and 40 mm of the LED respectively.

Outcome measures were the influence of LED intensity and photosensor distance on penetration depth, porcine heart absorption coefficients, and the influence of living biological tissues with finger oximetry. In vivo experiment was also performed with a heart-lung machine to assess the performance of the prototype and detect different oxygen saturation.

Results

Increasing LED intensity induced higher photocurrent and increasing the source-detector distance decreased the photocurrent. In both cases, different tissue depths have been reached. Figure 2 showed that at low oxygen levels (deoxyhemoglobin (Hb)-rich blood), shorter wavelengths absorb most of the light. Signals of shorter wavelength are then proportional to *Hb* concentration and followed the oxygen saturation curve. Longer wavelengths are proportional to the concentration of HbO_2. Oxygen saturation was determined using the Modified Beer-Lambert law.

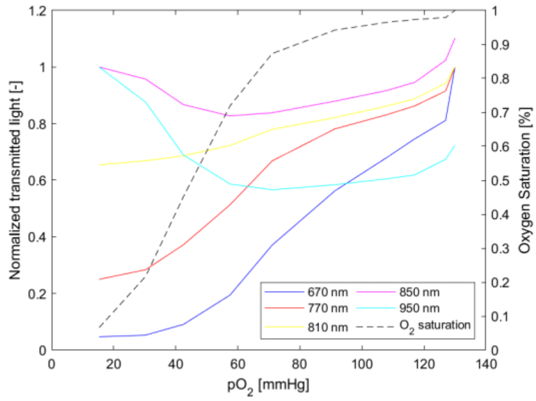

Fig. 2 Transmitted light as a function of oxygen partial pressure in mmHg. Received signals were recorded with the NIRS sensor. Oxygen saturation and partial pressure were recorded with a gas analyzer.

Discussion

Measurements with biological tissue showed that transmitted light was coming from different tissue depths depending on LED intensities and photosensors distances. In vitro experiments with the heart-lung machine assess that oxygen saturation can be measured. The spectral bandwidth of both LED and photosensors can influence the measurements. As no other study was performed to measure myoglobin oxygenation in myocardial tissue through the esophagus, in vivo experiments using a flexible circuit would determine the influence of human tissue on measurements. While the NIRS sensor is a promising and non-invasive technology to measure ischemia during a surgical procedure.

References

[1] R. Kortum and E. Sevick, Quantitative Optical Spectroscopy for Tissue Diagnosis,
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