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DESIGN AND EVALUATION OF A NEW ELECTRO-OPTICAL SYSTEM FOR MONITORING OESOPHAGEAL PHOTOPLETHYSMOGRAPHS

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Abstract: When peripheral perfusion is poor and barely pulsatile, arterial blood oxygen saturation (SpO_2) readings from commercial pulse oximeter probes placed peripherally can become unreliable or cease. The human oesophagus has been investigated as a potential measurement site on the hypothesis that perfusion may be better preserved at this central site. A new reflectance photoplethysmographic (PPG) optical sensor and a signal processing and data acquisition system have been developed. Oesophageal PPG signals were obtained from 16 anaesthetised patients and displayed on a laptop computer. PPGs with high signal-to-noise ratio at two wavelengths (red and infrared) and five oesophageal depths were recorded. Signals from the middle oesophagus were larger than those from the upper and deep oesophagus.

Introduction

The continuous non-invasive monitoring of arterial blood oxygen saturation (SpO_2) by pulse oximetry often fails in patients with compromised peripheral perfusion. Conventional pulse oximeters usually monitor at the finger, ear or toe and are pulse dependent. Any significant reduction in the pulsatile component of the photoplethysmographic (PPG) signal can lead to dubious values for blood oxygenation or complete failure.

Peripheral perfusion is often poor and barely pulsatile in patients undergoing prolonged operations such as cardiac, vascular or reconstructive surgery. In these circumstances the SpO_2 readings from commercial pulse oximeters can become unreliable or cease at a time when they are most needed [1]. To overcome this limitation, the oesophagus has been investigated as a potential measurement site on the hypothesis that perfusion may well be better preserved at this central site. Preliminary studies using an earlier prototype system have shown that measurable PPG signals at 655 nm and 880 nm can be detected in the deep oesophagus [2][3]. A new system to investigate the morphology and quality of PPG signals from the entire length of the oesophagus has been developed and is described.

Materials and Methods

A reflectance optical sensor has been constructed comprising miniature infrared and red emitters and a photodetector. The sensor was design to fit into a conventional disposable transparent stomach tube, 20 French gauge. A new isolated data acquisition and processing system has been developed to detect, pre-process, sample, record and display simultaneously the red and infrared AC and DC PPG signals. A block diagram of the system is shown in Figure 1.

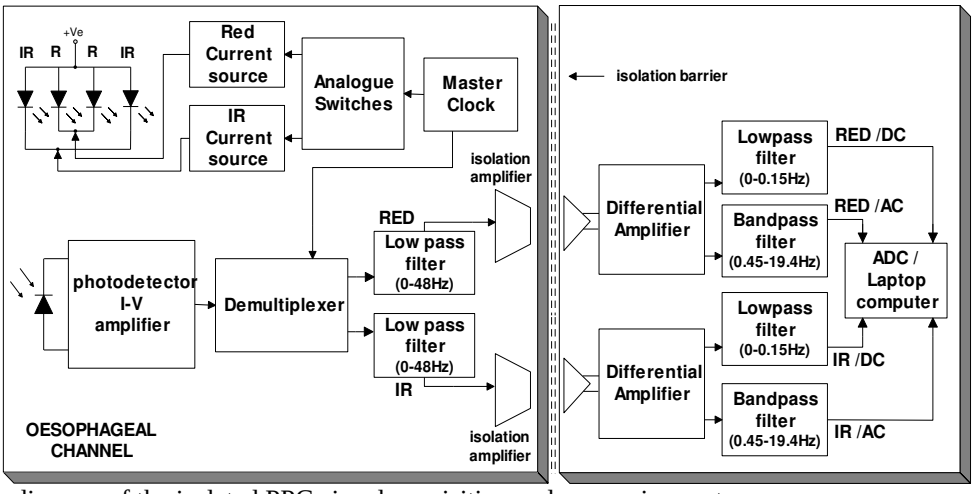

Figure 1: Block diagram of the isolated PPG signal acquisition and processing system

The emitters (red and infrared) are driven by constant current sources which are controlled by analogue switches which turn the red and infrared emitters on and off at 300 Hz. The photodetector detects the energy backscattered by the tissue and gives an output current proportional to the detected light intensity. The output of the photodetector amplifier contains multiplexed PPG signals at red and infrared wavelengths. The signal from the current-to-voltage (I-V) amplifier passes to a demultiplexer synchronised to the master clock which separates the red (R) and infrared (IR) signals. The two signals (R and IR) are then passed through low pass filters to eliminate high-frequency switching transients and are then transmitted across an isolation barrier. Two isolation amplifiers (HCPL7820), are used to isolate the patient side of the PPG channel from the output side. The signals on the output side are amplified by differential amplifiers and filters are used to extract the AC and DC PPG components for each wavelength. The output signals are digitised and further analysed by a virtual instrument implemented in Labview on a laptop computer. Infrared and red AC and DC PPG traces were obtained simultaneously and displayed on the laptop screen.

Sixteen healthy adult patients were studied who were to undergo tracheal intubation as a routine part of general anaesthesia for elective urological, gynaecological and general surgery. The oesophageal PPG sensor within the stomach tube was inserted through the mouth into the oesophagus and was advanced under direct vision until the probe was 35 cm from the upper incisors. PPG traces from the oesophagus at red and infrared wavelengths were recorded simultaneously for approximately 5 minutes at this depth. Measurements were repeated at 30, 25, 20 and 15 cm from the upper incisors.

Results

Measurable PPG traces at both wavelengths were obtained in the oesophagus at all five depths. Typical traces at 15 cm, and 25 cm are shown in Figure 2.

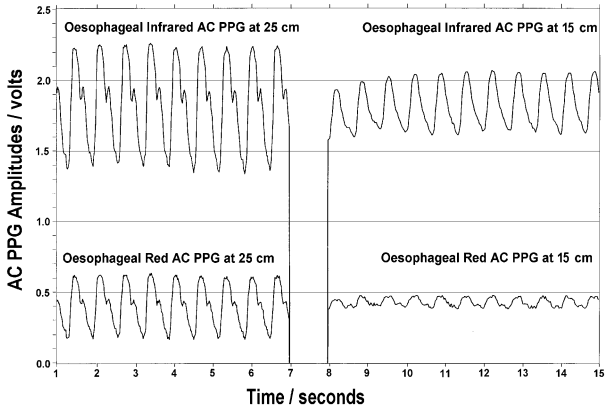

Figure 2: AC PPG traces for the R and IR wavelengths measured at 25 cm, and 15 cm from the upper incisors.

The AC PPG signals at 20 cm, 25 cm, and 30 cm, on average, had larger amplitudes at R and IR wavelengths than the PPGs at 15 cm, and 35 cm (see Figure 3).

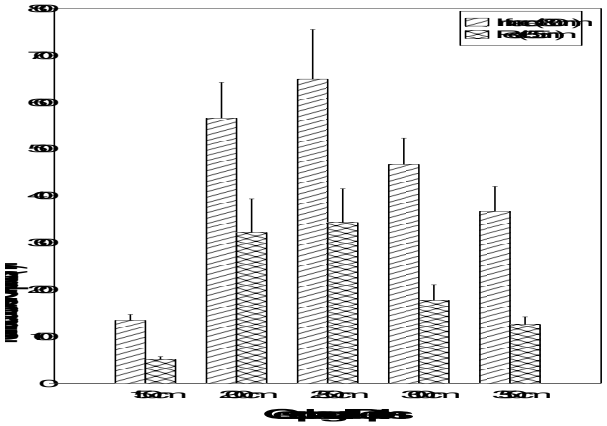

Figure 3: Mean (Std. Error) AC PPG Peak-to-Peak Amplitudes at two wavelengths and five Depths

Discussion and Conclusions

A new oesophageal reflectance optical sensor and a data acquisition system have been developed which allow AC and DC PPG measurements at red and infrared wavelengths to be made simultaneously. The system allows measurements within the whole length of the oesophagus. Oesophageal PPGs have been obtained with high signal-to-noise ratio at R and IR wavelengths at five depths. The maximum PPG amplitudes, and therefore the optimum monitoring depth, appears to be in the mid-oesophagus at 25 cm. Both wavelengths used are suitable for pulse oximetry. Hence, these results justify further studies to evaluate the mid-oesophagus as a potential site for blood oxygen saturation monitoring in patients with poor peripheral perfusion.

Acknowledgements

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