Development of a Ring-Shaped Pulse Oximeter to Analyse Angle Dependency in SpO2 Estimation

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Aims: This work aimed to analyse the angle dependency of blood oxygen saturation (SpO_2) estimation with photoplethysmography (PPG), a noninvasive method typically using two light-emitting diodes (LED) and a photodiode (PD). A device-specific, geometry-dependent calibration curve, which correlates the Ratio-of-modulation (R) with SpO_2 values, is commonly established using linear regression, where the R-value is defined as the ratio of the quotients of pulsatile to non-pulsatile components of the PPG signals for red and infrared light.

Methods: A ring-shaped PPG sensor with an integrated optoelectronic system was developed using a 660 nm and a 940 nm LED and four PDs at different angles (40°, 45°, 90°, and 135°). The sensor was controlled with an Arduino Nano using a photometric ADPD105 front-end. We performed a hypoxia study to induce SpO_2 values between 100 % and 85 % on five young healthy subjects. PPG data from the ring-shaped sensor and SpO_2 data from a reference pulse oximeter were collected and analysed using MATLAB.

Results: The measurements showed high inter-individual variability of the signal quality due to the inadequate fitting of the ring to the individual finger morphology. However, results from good-quality signals showed a clear angle dependency: transmissive configurations at 90° presented conventional R-values between 0.4 and 1 for SpO_2 values between 100 % and 85 %, and reflective configurations at 45° showed R-values between 1 and 1.4.

Conclusion: This work demonstrates the differences in SpO_2 estimation for transmissive and reflective configurations of PPG. However, for further research, it is recommended that the ring-shaped sensors be customised for each subject to increase signal quality and comparable PPG data from different angles. The analysis of the data collected with the improved setup could yield a significant advance in understanding the origin of PPG signals and enhancing its accuracy in clinical settings.