Model-based Analysis of Pulse Transit Time Characteristics During Obstructive Apnea

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Context: The pulse transit time (PTT) is the time delay between the ECG R wave and the arrival of the pulse wave at a peripheral site, detected via photoplethysmography (PPG). PTT has been used in the context of sleep apnea syndrome (SAS) to detect and characterize apneas, since it is correlated to respiratory effort. However, the mechanisms behind this correlation remain to be explored. This work investigates the modulation of PTT associated with obstructive apneas, through a physiological model-based method.

Methods: Obstructive apnea episodes have been simulated using an integrated model of cardio-respiratory interactions including: i) ventilation, ii) cardiovascular circulation with a finger compartment for PPG representation, iii) gas exchange and transport, and iv) neural control. The finger capillary pressure was used as a PPG analog for the calculation of PTT and simulation results were compared with SAS patient data. The sensitivity to the 218 model parameters was evaluated for PTT and PTT oscillations (ΔPTT), before, during and after the apnea, using Morris's method.

Results: The mean baseline simulated PTT was 251 ms with a mean ΔPTT of 11 ms, consistent with the patient data of 251 $\pm$ 16 ms and 17 $\pm$ 7 ms. The most influent parameters on PTT and ΔPTT were related to cardiac contractility, heart rate control, baroreflex, and venous unstressed volume. ΔPTT was also influenced by central chemoreceptors and pulmonary CO_2 concentration parameters. These findings are consistent with the literature.

Conclusion: Results highlight the most sensitive parameters of an integrated mathematical model on PTT modulation during apnea. Further work will focus on a patient-specific identification of these parameters in order to reproduce data observed from polysomnographic studies.