Sensitivity Analysis of a Cardiorespiratory Model for Pulse Transit Time

Arthur Ben-Tolila*[1], Virginie Le Rolle[1], Alfredo I. Hernández[1]

[1]Univ Rennes, Inserm, LTSI - UMR 1099, F-35000 Rennes, France

Context: The pulse transit time (PTT) is the pulse pressure delay between two arterial sites, typically computed between the ECG R wave and the pulse arrival at the periphery, measured via photoplethysmography. PTT analysis has shown promising results for blood pressure estimation and apnea characterization. However, the dynamics of the PTT remain poorly exploited. A model-based approach is proposed in this work to investigate the main modulating parameters of PPT dynamics.

Methods: An integrated cardio-respiratory model, previously developed in our laboratory, including: i) cardiovascular system, ii) respiration, iii) gas exchange/transport, was enriched with a finger compartment in order to study its specific dynamics. The PTT was estimated between the left ventricle activation time and the maximum slope of the modeled finger capillary blood pressure. Sensitivity of the mean PTT and the difference between the minimum and maximum PTT (ΔPTT) to the 112 model parameters was studied using Morris's method, in a range of $\pm 30\%$ of their nominal value. Sensitivity was quantified for each parameter i through $D_i = \sqrt{(\mu_i^*)^2 + (\sigma_i)^2}$, where μ_i^* and σ_i are the mean of the absolute value of elementary effects, and their standard deviation, respectively.

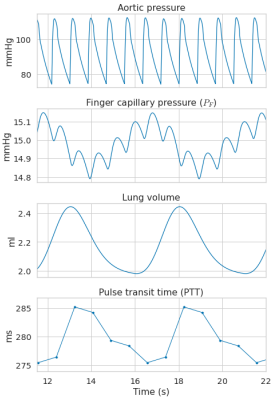

Fig. 1: Simulation results

Results: Simulated PPT values are consistent with those typically observed in healthy adults, with a mean PTT of 279.96 ms and a ΔPTT of 11.72 ms. The mean PTT was particularly sensitive to the parameters defining ventricular elastance (accounting for 38.87% of the sum of D_i), finger vasculature (16.08%) and systemic arteries (14.74%). For ΔPTT, finger vasculature (30.46%), respiratory muscle activity (23.29%) and ventricular elastance parameters (12.98%) had the greatest effects.

Conclusion: These results provide valuable information for the application of such an integrated model to the analysis of PTT signals. In particular, they suggest a convenient set of parameters to be identified in a subject-specific manner in future works.