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Algorithm Development of Individual Lumped Parameter Modelling for Blood Circulatory System: An Optimization Study

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Abstract : Background: Lumped parameter model (LPM) is a common numerical model for hemodynamic calculation. LPM uses circuit elements to simulate the human blood circulatory system. Physiological indicators and characteristics can be acquired through the model. However, due to the different physiological indicators of each individual, parameters in LPM should be personalized in order for convincing calculated results, which can reflect the individual physiological information. This study aimed to develop an automatic and effective optimization method to personalize the parameters in LPM of the blood circulatory system, which is of great significance to the numerical simulation of individual hemodynamics. Methods: A closed-loop LPM of the human blood circulatory system that is applicable for most persons were established based on the anatomical structures and physiological parameters. The patient-specific physiological data of 5 volunteers were non-invasively collected as personalized objectives of individual LPM. In this study, the blood pressure and flow rate of heart, brain, and limbs were the main concerns. The collected systolic blood pressure, diastolic blood pressure, cardiac output, and heart rate were set as objective data, and the waveforms of carotid artery flow and ankle pressure were set as objective waveforms. Aiming at the collected data and waveforms, sensitivity analysis of each parameter in LPM was conducted to determine the sensitive parameters that have an obvious influence on the objectives. Simulated annealing was adopted to iteratively optimize the sensitive parameters, and the objective function during optimization was the root mean square error between the collected waveforms and data and simulated waveforms and data. Each parameter in LPM was optimized 500 times. Results: In this study, the sensitive parameters in LPM were optimized according to the collected data of 5 individuals. Results show a slight error between collected and simulated data. The average relative root mean square error of all optimization objectives of 5 samples were 2.21%, 3.59%, 4.75%, 4.24%, and 3.56%, respectively. Conclusions: Slight error demonstrated good effects of optimization. The individual modeling algorithm developed in this study can effectively achieve the individualization of LPM for the blood circulatory system. LPM with individual parameters can output the individual physiological indicators after optimization, which are applicable for the numerical simulation of patient-specific hemodynamics.

Keywords : blood circulatory system, individual physiological indicators, lumped parameter model, optimization algorithm
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