

Coupling the Guyton Model to Pulsatile Ventricles using a Multiresolution Modelling Environment

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The pioneering work of Guyton, Coleman, and Granger (1972) provided an interesting multi-organ, lumped-parameter model of the global cardiovascular system and its regulation. However, this model (G72) does not include a pulsatile representation of the cardiac function and thus cannot be used for a beat-to-beat analysis. Within the framework of the SAPHIR project, the G72 model has been re-implemented by using an object-oriented multiresolution modeling tool, developed in our laboratory (M2SL). In this paper, we propose the substitution of the original, non-pulsatile cardiac sub-model of the G72 model by an elastance-based pulsatile model of the heart, including interventricular interaction through the septum. This substitution process is not simple, as it requires the identification of the pulsatile model parameters that will preserve the stability and physiological properties of the G72 model, as well as and the appropriate handling of the heterogeneous time-scales that will be involved within the new model. An identification algorithm has been thus applied to reproduce benchmark data from the original G72 model with the modified, pulsatile version of the model. The error function being minimized has been defined as the mean square error of eight physiological variables calculated between the outputs from both models (urinary output, muscle venous oxygen pressure, muscle cell oxygen pressure, mean arterial pressure, sympathetic stimulation, cardiac output, muscle blood flow and rate of oxygen usage by muscle cells). After parameter identification, the mean square error for the eight signals is equal to 0.0108. Results show how a higher-resolution model allows the simulation of realistic pulsatile ventricular pressures while keeping the main physiological properties of the original model. Besides, this is an example of how multiorgan models such as those proposed by Guyton could be used as a core-model to integrate higher-resolution models, allowing for a better representation of appropriate boundary conditions.