Asociación Argentina de Mecánica Computacional

Mecánica Computacional Vol XXXI, págs. 3-3 (resumen)
Alberto Cardona, Paul H. Kohan, Ricardo D. Quinteros, Mario A. Storti (Eds.)
Salta, Argentina, 13-16 Noviembre 2012

RECENT ADVANCES IN THE COMPUTATIONAL MODELING OF THE CARDIOVASCULAR SYSTEM AT HEMOLAB

Pablo J. Blanco and Raúl A. Feijóo

HeMoLab; LNCC/MCTI National Laboratory for Scientific Computing; INCT-MACC - National Institute of Science and Technology in Medicine Assisted by Scientific Computing, Brazil

Abstract. In recent decades we have seen the enormous growth of scientific publications seeking to model certain aspects of the behavior of the human cardiovascular system. Several of these publications have tried to represent its behavior using lumped models and distributed models capable to simulate the behavior of blood flow circulation in deformable arteries. As well, with the increasing accuracy of medical imaging, reconstruction of specific arterial geometry emerged allowing the modeling of local blood circulation in patient-specific arterial districts.

Nevertheless, a truly integrative modeling of the cardiovascular system in terms of global/local scales, further coupled with respiratory and neural control systems -just to mention two- has been missing, in part due to lack of data and in part due to lack of computational resources (modeling the entire cardiovascular system is still a formidable task).

Our aim with this talk is to describe the current state of our ADAN Model (Anatomical Detailed Arterial Network Model) of the Arterial Network. This model could be viewed as an ultimate bridging among anatomy, physiology and computational modeling by creating an arterial network following stringent anatomical and physiological considerations. This anatomically-consistent arterial topology incorporates almost every single arterial segment acknowledged in the medical community going up to 1.585 vessels, and with arteries having lumen radius ranging from 15mm (aorta artery) to 0,15mm (perforator arteries). This model serves as a framework to investigate, in-silico, a large number of cardiovascular conditions, and represents the state-of-the-art achieved within the HeMoLab group at the LNCC/MCTI (http://hemolab.lncc.br).

The ADAN Model is developed using heterogeneous mathematical representations. In fact, the blood flow in this network is simulated by using a one dimensional (1D) model for the arterial segments allowing the simulation of the wave propagation phenomenon in the detailed arterial network including the wave reflections occurring at branching sites, bifurcations, and at any other location with impedance mismatch interfaces. At each outflow point we incorporate the peripheral circulation in arterioles and capillaries by using 0D three-component Windkessel models. In turn, the whole peripheral circulation converges to the venous system through the upper and lower parts of the body. These two main compartments are represented using lumped models for the venules, veins and cavas (inferior and superior). The right and left heart circulations, as well as the pulmonary circulation are also modeled by means of 0D models. Particularly we point out the modeling of the four heart valves, which is carried out by using a non-linear model which allows for the regurgitation phase during the valve closing. Finally, the 0D model of the left ventricle is coupled with the inflow boundary in the 1D model, closing the cardiovascular loop. Moreover, we consider the existence of 3D models accounting for all the complexity of three-dimensional blood flow in specific vessels of interest.

Finally, the (i) calibration of this model will be raised, involving the setting of vessel and terminal parameters, and some simulations of the hemodynamics in the upper and lower limbs; (ii) integration of our cardiovascular system with the neural and respiratory systems; (iii) extension of the CCO method for automatic vascular generation for organs and vascular territories; (iv) characterization of mechanical properties of coronary arteries wall tissues using IVUS medical image data synchronized with the ECG of the patient; (v) development of a new variational formulation for multiscale constitutive modeling for arterial wall tissue including softening and damage and its applications to aneurismal risk rupture; will be also addressed in this talk.

In this context, we are convinced that this model will contribute to (i) understand the complex systemic interaction taking place at the different scales in the cardiovascular system and between others physiological system, (ii) make modeling-based diagnoses, (iii) perform accurate surgical planning, and (iv) aid in the simulation-based medical training and education.