Asociación Argentina
de Mecánica Computacional

Mecánica Computacional Vol XXVIII, págs. 3-3 (resumen)
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Tandil, Argentina, 3-6 Noviembre 2009

PRESENT AND FUTURE TRENDS IN THE MODELING AND SIMULATION OF THE CARDIOVASCULAR SYSTEM AT THE INCT-MACC

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Abstract. Cardiovascular diseases (CVD), are, and will remain to be, the leading cause of death in the world, including countries like Brazil and Argentina. In particular, ischemic heart disease and cerebrovascular diseases together account for 30% of deaths in developed countries. The social significance of CVD in Brazil is of identical relevance because they represent the main cause of retirement, the second leading cause of hospitalization and the leading cause of spending on these admissions.

In the last 10 years there has been a growing activity in the international scientific community concerned with the development of mathematical models and numerical methods for the computational modeling and simulation of the cardiovascular system under normal and altered conditions due to diseases and/or medical procedures. This has been motivated by the medical community that demanded a rigorous scientific research able to study and establish the causes of the onset and development of several CVD such as: arterioscleroses, aneurysms, mechanisms related to the reduction of the arterial lumen (artery occlusion) and atheroma plaque rupture events with its serious consequences.

Advances in fluid mechanics, fluid-solid interaction, in vivo mechanical properties characterization, image processing, mathematical modeling and computer simulation (including the interaction between different scales in the problem), scientific visualization, together with the notorious increase in the performance of computers, have allowed the development of sophisticated models comprising a breakthrough in research of the human cardiovascular system. Some results and original contributions in these areas were obtained by members of the INCT-MACC National Institute of Science and Technology in Medicine Assisted by Scientific Computing.

Our aims in this talk is to show the present and future trends in the modeling of the cardiovascular system obtained through a collaborative work with researchers from the three INCT-MACC's Associated Laboratories in Argentina. In particular a multiscale 3D-1D-0D model will be described in some details and several numerical simulations of cerebral and abdominal aneurysms will also be presented by using patient-specific medical images and geometry reconstruction.

Furthermore, the composition of plaque is a major determinant of clinical syndromes and additionally, vulnerability of plaque is influenced by the mechanical properties of the vessel wall and by the plaque and arterial geometry. Studies revealed that a thin cap overlying fatty tissue may be unable to bear the imposed stress caused by the pulsatile pressure of the blood. Lipid-rich lesions with a thin cap and local inflammatory response are considered rupture prone, which may lead to subsequent thrombosis and myocardial ischemia. Therefore, techniques that are capable of characterizing in vivo mechanical properties of the arterial wall tissues are of great interest from diagnostic, prognostic, and surgical planning point of view. For these reasons the true geometry and the in vivo property characterization of coronary arteries were chosen for a R&D collaborative activities network developed and promoted by this INCT-MACC National Institute.