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ONE DIMENSIONAL NUMERICAL MODELS FOR SIMULATION OF THE BLOOD FLOW ON ARTERIES.

***Soudah.E.[1] and Oñate.E.[1]**

[1] International Center for Numerical Methods in Engineering(CIMNE)
Technical University of Catalonia. Barcelona, 08034, Spain,
esoudah@cimne.upc.edu

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ABSTRACT

Cardiovascular disease remains the biggest killer of men and women, often in middle age, in developed society. It is the disease that causes more deaths than any other in the world (including AIDS, tuberculosis, malaria and cancer). In a number of European countries more than 50% of all deaths are due to cardio- and cerebrovascular disease. Cardiovascular disease also inflicts great suffering to patients. According to WHO estimates, 17 million people around the globe die of cardiovascular disease (CVD) each year. About 600 million people with high blood pressure are at risk of heart attack, stroke and cardiac failure. By 2010 CVD is estimated to be the major cause of death in developed countries.

This huge impact has motivated the development of numerical models for arterial behaviour in order to include cardiovascular pathologies and interventions. In general, 3D computer simulations of the whole cardiovascular system and specific surgical interventions are computational expensive and often require hours of time on parallel computers. This level of computation is necessary for obtaining detailed information about blood flow, but likely is unnecessary for obtaining information about mean flow rates and pressure losses.

In this work a coupled fluid-structure interaction one-dimensional model for the human cardiovascular system has been developed in order to study the vessel deformation and mean blood flow rate and pressure. The governing system[1][2] are a Hyperbolic system obtained from applying conservation of mass and momentum in a 1-D impermeable and deformable tubular control volume(cylindrical straight element) to the Navier-Stokes equations to an incompressible viscous fluid in a compliant tubes. The wall behaviour of the vessels (compliant tubes) is modelled by linear and non-linear elastic membranes[3]. To solve the equations, a Taylor-Galerkin scheme and an explicit four-order Runge-Kutta time integration scheme have been implemented.

The aim of this work is to develop and validate a new numerical scheme with experimental measures of the flow profile obtained by high resolution magnetic resonance and ultrasound techniques.

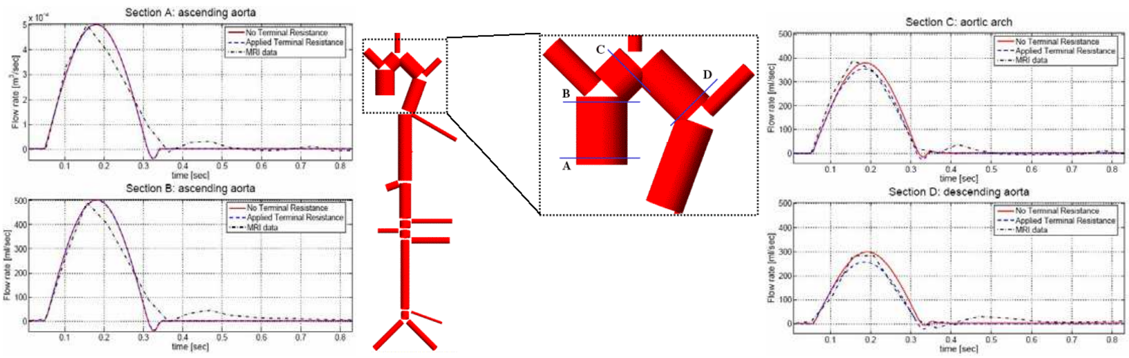

Figure 1: Schematic representation of the arterial network simulated. Flow velocity over one cardiac cycle in sections A,B,C,D.

This method is applied to compute flow rate and pressure in a single segment model [4], a bifurcation, a real model of the aorta(figure 1) and whole arterial system. Most of these solutions were obtained in less than 5 minutes of computation time on a personal computer.

The former one-dimensional model is coupled with a three-dimensional model in order to appropriately set inflow and outflow boundary conditions for multidimensional zones. This methodology is applied to solve 3D fluid-structure interaction with real boundary conditions of the femoral bifurcation[5].

This model provides useful information to set both inflow and outflow boundary conditions for 3D finite elements problems and could be helpful for the early detection, diagnosis and prevention of related arterial diseases.

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