

## Stability and control of the blood flow in the arterial vessels as multilayered anisotropic tubes

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The arterial vessels are multilayered tubes formed by the inner mechanosensitive layer (intima), middle muscle layer (media) and outer connective tissue layer reinforced by two families of collagen fibres (adventitia). The intravascular blood flow and pressure control is carried out by contraction/relaxation of the smooth muscle cells in media. The corresponding electrical signal is initiated by the intima cells depending on the shear rate at the wall and the hydrostatic pressure (Bayliss effect)<sup>1</sup>. The thickness and rheological parameters of the layers noticeably vary at different pathology like atherosclerosis, hypertension, chronic hypoxia, thromboembolism, fibrosis, and necrosis. As a result the density, viscosity, Young modules and thickness of the layers vary.

In this paper the influence of the mentioned material parameters on the blood flow stability and flow parameters is studied. The Navier-Stokes equations and the 3D viscoelasticity equations for the incompressible layers are solved with the fluid-solid interaction boundary conditions at the fluid-solid interface and the no displacement and no stress boundary conditions at the outer surface of the vessel wall. An original numerical procedure<sup>2</sup> and the asymptotic expansion of the solution in terms of a small parameter<sup>3</sup> have been applied. The stable and unstable fluid and solid base modes, the flow and shear stress profiles have been computed and compared for the both normal and pathological conditions. It was shown an increase in the shear modulus of the inner and middle layers decreases the temporal amplification rate and stabilizes the system whereas some increase in rigidity of the outer layer eliminates the temporal instability of a steady viscous flow in a compliant tube. Comparative analysis of system stability at the no displacement and no stress boundary conditions at the outer surface of the duct revealed that stabilization of the system can be achieved in both cases by increasing the rigidity of the inner layer. For a transversely anisotropic material, temporal stability can be achieved by increasing the shear modulus in the plane of isotropy of any of the layers at the no stress boundary condition, and by increasing the viscosity of the second layer at the no displacement conditions. It was shown the pathological variation in the wall parameters could be considered as adaptive adjustments of the blood vessels to the increased pressure and shear stress at the wall. The obtained results reveal the way the blood vessel wall adjust itself to stabilize the blood flow through the vessel by changing the values of the thickness, density, shear moduli and viscosities of the three layers composing the blood vessel wall.

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<sup>1</sup> Kizilova, Hamadiche and Gad-el-Hak, *Intern. J. Flow Control.*, **1**,199 (2009).

<sup>2</sup> Hamadiche and Kizilova, *Intern.J.Dynam.Fluids*, **1**, 1 (2005).

<sup>3</sup> Kizilova, *Fluid Dynamics*, **41**, 444 (2006).