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A MODEL APPROACH TO UNDERSTAND BLOOD CLOTTING DYNAMICS

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The process of platelet activation and blood coagulation is very complex and not yet well understood. Experimental studies recognize that thrombus formation can occur within blood vessels bifurcations, branching or strong curvature regions. Moreover, internal cardiovascular devices such as prosthetic heart valves, ventricular assist devices and stents foster high hemodynamic shear stresses that can cause platelet activation and clot formation. On the other hand, diseases due to dysfunctions of the hemostatic system are also of primary importance.

Knowing that laboratory experiments are usually very expensive and time consuming, an investment in comprehensive, reliable and easy to handle mathematical models can contribute to a better understanding of these complex phenomena [2–5].

Hereby, we present a mathematical model for platelets-fibrin clot formation and its evolution affected by the blood flow within a small artery [1]. Due to the process complexity leading to extremely complicated mathematical models, an appropriate reduction of a biochemical network has been introduced. The initial and amplification phases of the coagulation process including 10 advection-reaction-diffusion equations have been replaced by one virtual equation for prothrombinase production. Moreover, platelets action on a biochemistry cascade has been included and the Navier's slip boundary conditions for the blood flow have been imposed showing their importance in platelets and biochemistry provision towards the clotting region.

To model the biochemical cascade a system of 13 advection-reaction-diffusion equations coupled to each other through the reaction terms has been used. Furthermore, the blood flow was modeled as a generalized Newtonian fluid where the Navier's slip boundary conditions were imposed to model the slip velocity along the blood vessel walls. The whole coupled system of biochemistry and blood flow was solved using a finite element method.

Three-dimensional simulations of a blood clot formation and its evolution affected by the blood flow will be presented. Moreover, biochemistry concentrations dynamics inside the clot and in its vicinity will be analyzed.

REFERENCES

[1] A. Fasano, J. Pavlova and A. Sequeira, A synthetic model for blood coagulation including blood slip at the vessel wall, Clinical Hemorheology and Microcirculation 51(1), 1–14, 2012.

[2] A. Fasano, R.F. Santos and A. Sequeira, Blood coagulation: A puzzle for biologists, a maze for mathematicians, Modeling, Simulation and Applications Vol. 5, 41–75, 2012.

[3] M. Anand, K. Rajagopal and K.R. Rajagopal, A model for the formation, growth, and lysis of clots in quiescent plasma. A comparison between the effects of antithrombin III deficiency and protein C deficiency, Journal of Theoretical Biology, 253, 725–738, 2008.

[4] M. Anand, K. Rajagopal and K.R. Rajagopal, A model incorporating some of the mechanical and biochemical factors underlying clot formation and dissolution in flowing blood. Journal of Theoretical Medicine 5(3–4): 183–218, 2003.

[5] T. Bodnár, T. and A. Sequeira, Numerical simulation of the coagulation dynamics of blood, Computational and Mathematical Methods in Medicine, 9 (2), 83–04, 2008.