Mathematical Modelling and Numerical Simulations of Thrombus Growth

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Abstract

Blood coagulation is an extremely complex biological process in which blood forms clots to prevent bleeding, following by their dissolution and the subsequent repair of the injured tissue. The process involves different interactions between the plasma, the vessel wall and platelets with a huge impact of the flowing blood on the thrombus growth regularization.

A new mathematical model and some numerical results for thrombus development will be presented in this talk. The cascade of biochemical reactions interacting with the platelets, resulting in a fibrin-platelets clot production and the additional blood flow influence on thrombus development will be discussed. Two main aspects will be considered. The first one is the mathematical model reduction in terms of biochemical reactions to simplify the model complexity, allowing results in agreement with experimental data. Therefore, the process will be initiated at the propagation phase, when the dominant part of thrombin and fibrin are produced. That requires an appropriate choice of the initial

and boundary conditions to guarantee the prospective process development. A virtual equation to maintain the reliable prothrombinase production and additional platelets impact to the blood clot evolution is also included. The second feature of the model is to include the slip velocity and the consequent supply of activated platelets in the clot region, showing its importance on the whole blood coagulation process.

The model consists of a system of 13 nonlinear convection-reaction-diffusion equations, describing the cascade of biochemical reactions, coupled with a non-Newtonian model for the blood. Numerical results will be presented in a three-dimensional blood vessel, using the finite element method. Blood clot formation, due to platelets supply and its evolution affected by blood flow will be discussed. Moreover, several cases of coagulation disorders leading to system perturbations all be presented and compared with experimental results. The main objective of this study is to build a blood coagulation model able to predict effects of specific perturbations in the hemostatic system that can't be obtained by laboratory tests, and assist in clinical diagnosis and therapies of blood coagulation diseases.

Keywords: Blood coagulation, platelets, biochemical reactions, mathematical modelling, slip boundary conditions, reaction-advection-diffusion equations

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] J. Pavlova, Mathematical modelling and numerical simulations of blood coagulation, PhD Thesis, Lisbon University, 2014.

[3] J. Janela, J. Pavlova, A. Sequeira, A Synthetic cell-based model for blood clot modelling, Proceedings of CMMSE 2014, 2014. ISBN 978-84-616-9216-3, ISSN 2312-0177.

[4] J. Pavlova, A. Fasano, J. Janela and A. Sequeira, Numerical validation of a synthetic cell-based model of blood coagulation (Submitted).

[5] J. Pavlova, A. Fasano, A. Sequeira, Numerical simulations of a reduced model for blood coagulation (Submitted).