

Identifying Key Transport Mechanisms in the Formation of Thrombi

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The overall goal of this project is to better understand the transport mechanisms involved in blood clot formation. This ERIF is allowing partial support of one graduate student research assistant, Sahar Hendabadi, for a duration of 12 months to help initiate work towards accomplishing this objective. Below we have outlined the progress made during the past 5 months related to this effort.

Ms. Hendabadi has gained considerable experience applying the computation of finite time Lyapunov exponents (FTLE) to fluid flow problems. These computations can be used to find separatrices in time-dependent flows referred to as Lagrangian Coherent Structures (LCS). These structures divide dynamically distinct regions in the flow and reveal transport information that is hidden from traditional visualization methods. We are utilizing LCS computations to understand transport in and around forming blood clots.

We have established a collaboration with a thrombosis modeling effort at Notre Dame University that complements our transport analysis. Specifically, we have obtained and compiled a multiscale clot simulation code developed by Mark Alber and Zhilang Xu at Notre Dame. This model consists of three submodels: (A) biochemical reactions sub-model used to describe the coagulation cascade; (B) cell sub-mode that represents different cell types and describes cell-cell and platelet-injury adhesion, platelet activation, cell movements, cell state changes and platelet aggregation; (C) flow sub-model composed of incompressible Navier-Stokes equations with Darcy's law describe dynamics of viscous blood plasma. We are currently running simulations using this multiscale approach and postprocessing the results with LCS computations.

In a related project, Ms. Hendabadi has developed software to perform sensitivity analysis of the coagulation model developed by the Notre Dame group using FTLE concepts. Since the empirically derived rate constants governing the dynamics of biochemical coagulation processes are not known with certainty, there is a need to better understand the sensitivity of this model to variations in the parameters. This analysis is helping with the modeling effort and the overall objective of this project, but furthermore represents a novel implementation of the FTLE approach, which previously has only considered sensitivity to variations in initial conditions.

We are currently working on installing and compiling software, Simvascular, on the Andrea computing cluster used by our group. This software will enable modeling of complicated vascular geometries not capable of being analyzed by the modeling tools from the Notre Dame group. Specifically, we are targeting pathological conditions such as stenotic geometries, to understand how such anatomical changes influence transport properties that may dictate where and how associated clot formation occurs. We are also working in collaboration with Vincent Turrito's postdoc, Megan Francis-Sedlak, to obtain in vitro validation of these results.