Mathematical Models for Biomedical Problems

Short Course
University of Ferrara, Italy - 2016

1. Fundamentals of the Circulatory System
Anatomy of the arterial system.
Hemodynamics in large and medium size arteries: modeling and physiology.
Blood rheology; vessel walls histology. Clinical problems that alter the mechanical properties of blood and arterial walls: sickle cell anemia; atherosclerosis; aneurysms.

2. Constitutive Models for Blood
Review of kinematics and constitutive models for fluid flows.
Generalized Newtonian and viscoelastic models.
Modeling blood as a Navier-Stokes fluid: overview of theoretical results and numerical techniques.
Hierarchical reduced models: 1D and 0D models – derivation and analysis.

3. Simplified Mathematical Models for the Vessel Wall
Mathematical analysis of some vessel wall models: energy inequalities.

4. Coupled Models for Fluid-Structure Interaction Problems
Coupling the vessel wall models with the fluid equations: the Arbitrary Lagrangian Eulerian (ALE) formulation of fluid motion in compliant vessels. Navier-Stokes equations in the ALE frame. Energy inequalities for the fluid-structure interaction problem.
Algorithms for FSI problems and numerical results in vascular geometries.
The geometrical multiscale approach to couple FSI and 1D models.

5. Clinical Applications
Blood coagulation modeling and simulations.
Blood flow simulations in patient-specific cerebral aneurysms.
Mathematical models of atherosclerosis.

BIBLIOGRAPHY

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* A.M. Robertson, A. Sequeira, M. Kameneva, Hemorheology, in: *Hemodynamical Flows: Modeling, Analysis and Simulation,* Series: Oberwolfach Seminars, Vol. 37, G.P. Galdi, R. Rannacher, A.M. Robertson, S. Turek, Birkhäuser, 63-120, 2008.
* A. Quarteroni, L. Formaggia, Mathematical Modelling and Numerical Simulation of the Cardiovascular System. In: Handbook of Numerical Analysis, Vol XII: Computational Models for the Human Body, N. Ayache (Ed), Elsevier, 2004.
* L. Formaggia, A. Quarteroni, A. Veneziani (Eds), *Cardiovascular Mathematics: Modeling and simulation of the circulatory system*, MS&A, Springer-Verlag, 2009.
* A. Quarteroni, A. Valli, *Numerical Approximation of Partial Differential Equations*, Springer-Verlag, New York, 1994.
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