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# MODELING BLOOD AS A LIVING TISSUE IN COMPUTATIONAL HEMODYNAMICS

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**MINI-SYMPOSIUM PROPOSAL**

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## 1 MINI-SYMPOSIUM PROPOSAL

Computational Fluid Dynamics (CFD) is now a well-established technique to get insight about hemodynamics in the cardio-vascular system and blood-wetted medical devices. Significant progress has been made during the last decade and the number of published papers in the domain has drastically increased. This rapid progress has been made possible thanks to the experience gained since the 80's in other research fields like aerodynamics, where CFD is being used as a key ingredient of any design and/or research effort. However, blood flows involve very specific properties that are not always present in other research fields and which have received little attention so far. Notably they deal with a very particular fluid, blood, which has several specific features:

- its rheology is extremely complex, including shear-thinning, thixotropic and two-phase flow effects [1],
- blood macro-circulation mostly happens in a pulsed transitional regime for which the laminar assumption usually made is not justified and the classical turbulence models are not accurate [2] and where interactions between blood and moving membranes are prominent
- blood is a bio-fluid which may be damaged (hemolysis [3]) if submitted to strong stresses or heat and whose structure may change (thrombosis [4]) depending on its recent history or exposure to foreign materials,

### 1.1 Objectives and expected contributions

Hemolysis and thrombosis are two manifestations of the living nature of blood. Their mathematical/numerical modelling are the subject of more and more intense research [3]–[6], but predictive models useable in practical computations are still lacking. One major difficulty in developing/validating such models is the large variability from sample to sample on top of the complexity of the physical phenomena themselves. The objective of this mini-symposium is to offer to the biomechanical community the opportunity to share experiences/ideas regarding the ways of introducing more complex blood models in macroscopic scale computations. Contributions are expected and strongly encouraged in the following areas: hemolysis or thrombosis modelling; multiscale computations; reduced-order models; parameters assessment; uncertainties quantification and propagation; experimental or clinical validation.

Hemolysis and thrombosis are both impacted by the time of residence of blood cells [4], [5], or at least the time of application of stress conditions. In terms of fluid mechanics, the characteristic time scales and local stresses strongly depend on the flow regime (laminar, transitional, turbulent);

appropriate turbulence modelling strategies as well as rheological model should be used in order to properly feed hemolysis/thrombosis models, although this is not the case in most of the current studies. Contributions questioning the robustness of the CFD outcomes with respect to the blood rheology and/or flow regime are thus also welcome.

### 1.2 Tentative list of speakers

Experts in the field like A. Fogelson (Utah), A. Figueroa (Michigan), D. Bluestein (Stonybrook), D. Ku (Georgia Tech), J. Antaki (Carnegie Mellon), J. Humphrey (Yale), K. Neeves (Mines Colorado), K. Sharp (Louiswille), M. Behr (Aachen, Germany), R. Mittal (Johns Hopkins), S. Yazdani (S. Alabama), S. Shadden (Berkley), Y. Ventikos (UCL, UK), Y. Xu (Imperial, UK) were already or will be shortly contacted to participate to this Mini-Symposium. We also expect to receive abstracts from researchers and engineers from other groups and/or companies interested in this topic.

## REFERENCES


[1] O. K. Baskurt and H. J. Meiselman, "Blood Rheology and Hemodynamics," *Semin. Thromb. Hemost.*, vol. 29, no. 5, pp. 435–450, 2003.

[2] L. Antiga and D. Steinman, "Rethinking turbulence in blood," *Biorheology*, vol. 46, pp. 77–81, 2009.

[3] A. Marsden, Y. Bazilevs, C. Long, and M. Behr, "Recent advances in computational methodology for simulation of mechanical circulatory assist devices," *WIREs Syst BiolMed*, vol. 6, pp. 169–188, 2014.

[4] S. Cito, M. D. Mazzeo, and L. Badimon, "A review of macroscopic thrombus modeling methods," *Thromb. Res.*, vol. 131, no. 2, pp. 116–124, 2013.

[5] K. H. Fraser, T. Zhang, M. E. Taskin, B. P. Griffith, and Z. J. Wu, "A Quantitative Comparison of Mechanical Blood Damage Parameters in Rotary Ventricular Assist Devices: Shear Stress, Exposure Time and Hemolysis Index," *J. Biomech. Eng.*, vol. 134, no. August, p. 081002, 2012.

[6] A. V Belyaev, J. L. Dunster, J. M. Gibbins, M. A. Panteleev, and V. Volpert, "Modeling thrombosis in silico : Frontiers , challenges , unresolved problems and milestones," *Phys. Life Rev.*, vol. 1, pp. 1–39, 2018.