DIVERGENCE-CONFORMING AND FULLY-IMPLICIT SIMULATION OF MICROSCALE BLOOD FLOW

H. Casquero[1*], C. Bona-Casas[2], H. Gomez[3], and Y. Zhang[1]

[1] Department of Mechanical Engineering
Carnegie Mellon University, Pittsburgh, PA 15213, USA.
[*] e-mail: hugocasquero.iccp@gmail.com

[2] Departament de Física,
Universitat de les Illes Balears, 07122 Palma de Mallorca, Spain

[3] Department of Mechanical Engineering
Purdue University 585 Purdue MallWest Lafayette, IN 47907

ABSTRACT

In the last decades, modeling of cell-scale blood flow has attracted remarkable attention in computational mechanics. In vessels with a diameter smaller than 500 μm, blood cells are explicitly included in the model to study various phenomena in which the own motion of individual blood cells is of interest. This leads to a fluid-structure interaction (FSI) problem in which both blood cells and blood plasma are incompressible. We have recently extended our immersed method for FSI [1-3] in order to utilize divergence-conforming B-splines for the spatial discretization while maintaining a fully-implicit time discretization. Divergence-conforming B-splines have already been proven to increase the accuracy and robustness of immersed FSI methods in [4]. We have also developed a scalable implementation of our method which is necessary to tackle the application of cell-scale blood flow. Our fluid solver is based on the scalable block-preconditioning strategy developed in [5].

We will show the effects of size, deformability, and density when it comes to islolate nucleated cells using mechanical means. This could help to improve existent medical devices to isolate circulating tumor cells from blood samples.

Finally, we will study the flow patterns and rheology of blood in normal and stenosed arterioles. The stenosis of arterioles can lead to important diseases as coronary microvascular disease and lacunar infarct. The flow characteristics of stenosed arterioles are quite different from those of macrovascular stenosis due to the fact that blood behaves as a Newtonian fluid in large arteries, but as a non-Newtonian fluid in arterioles.

REFERENCES

[1] H. Casquero, C. Bona-Casas, H. Gomez, A NURBS-based immersed methodology for fluid-structure interaction. *Computer Methods in Applied Mechanics and Engineering*, **284**, 943-970, 2015.

[2] H. Casquero, L. Liu, C. Bona-Casas, Y. Zhang, H. Gomez, A hybrid variational-collocation immersed method for fluid-structure interaction using unstructured T-splines. *International Journal for Numerical Methods and Engineering*, **105**, 855-888, 2016.

[3] H. Casquero, C. Bona-Casas, H. Gomez, NURBS-based numerical proxies for red blood cells and circulating tumor cells in microscale blood flow. *Computer Methods in Applied Mechanics and Engineering*, **316**, 646-667, 2017.

[4] D. Kamensky, MC. Hsu, Y. Yu, JA. Evans, MS. Sacks, TJR. Hughes. Immersogeometric cardiovascular fluid–structure interaction analysis with divergence-conforming B-splines. *Computer Methods in Applied Mechanics and Engineering*, **314**, 408-472, 2017.

[5] AMA. Côrtes, L. Dalcin, AF. Sarmiento, N. Collier, VM. Calo, A scalable block-preconditioning strategy for divergence-conforming B-spline discretizations of the Stokes problem. *Computer Methods in Applied Mechanics and Engineering*, **316**, 839-858, 2017.