Movement of circulating tumour cells in a capillary bifurcation of a microchannel

Natália Hajnovičová, Tímea Petáková, Thu Thao Tran Minh
University of Žilina
Faculty of Management and Informatics
Univerzitná 8215/1, 010 26 Žilina
hajnovicova.n@gmail.com
timeapetakova@gmail.com
vika.tran.minh@gmail.com

Abstract. *Circulating tumour cells (CTCs) and their clusters are critical biomarkers used in the diagnosis and prognosis of metastatic diseases. This work focuses on the numerical simulation of the dynamics of individual CTCs, two-cell clusters, and three-cell clusters in microfluidic channels with bifurcations. The simulations were performed using the ESPResSo environment, with the Lattice-Boltzmann method to model hydrodynamics, and the PyOIF spring-network model used to describe mechanical properties of the cells. The results suggest that clusters exhibit unique hydrodynamic properties, with their velocity in wider branches being higher than that of individual cells due to more efficient flow capture. This work defines optimal parameters for numerical stability and interaction potentials for modelling clusters in complex geometries.*

Keywords. circulating tumour cells, Lattice-Boltzmann method, PyOIF, microfluidic bifurcation, cell clusters

Acknowledgments

We would like to thank prof. Mgr. Ivan Cimrák, Dr. and Ing. Michal Mulík PhD. For their expert guidance, valuable advice. And constant support, which contributed significantly to the successful completion of this work.

References

[1] Vrynas, A., Bazban-Shotorbani, S., Arfan, S., Satia, K., Cunningham, B., Sagindykova, G., Ashna, M., Zhang, A., Visan, D., Chen, A., Matthews-Palmer, T., Carter, M., Blackhall, F., Simpson, K. L., Dive, C., Huang, P., & Au, S. H. (2025). Circulating Tumor Cells Shed Shearosome Extracellular Vesicles in Capillary Bifurcations That Activate Endothelial and Immune Cells. Advanced Science. Retrieved from https://doi.org/10.1002/advs.202506339

[2] ESPResSo Developers. (n.d.). ESPResSo documentation. Retrieved from https://espressomd.github.io/

[3] PyOIF Developers, (2022). PyOIF Documentation. Retrieved from https://www.dropbox.com/scl/fi/9jet7c4pf99g884id5boz/oif_documentation.pdf?rlkey=6bbw6dyivkds0tn89cvir1swa&e=2&dl=0

[4] ESPResSo Developers. (2019). Documentation: Lennard-Jones Interaction. Retrieved from https://espressomd.github.io/doc4.1.2/espressomd.html#espressomd.interactions.LennardJonesInteraction

[5] ParaView Developers. (2026). ParaView Documentation. Retrieved from https://docs.paraview.org/en/latest/

[6] LibreTexts. (2024). Lennard-Jones Potential. Retrieved from https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Physical_Properties_of_Matter/Atomic_and_Molecular_Properties/Intermolecular_Forces/Specific_Interactions/Lennard-Jones_Potential

[7] S. Dai, Ch., Mishra, A., Edd, J., Toner, M., Maheswaran, S., Haber, D.A., (2025). Circulating tumor cells: Blood-based detection, molecular biology, and clinical applications. Retrieved from Circulating tumor cells: Blood-based detection, molecular biology, and clinical applications: Cancer Cell