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A LOOK INTO THE MECHANICAL PROPERTIES OF SINGLE CELLS: A TWO-PHASE CFD MODEL AND ITS VALIDATION

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Summary: Introduction
Understanding the mechanical properties of cells is one of the most challenging topics in microfluidics. The development of numerical simulations able to represent the mechanical behaviour of different kinds of cells can help better understand altered or pathological conditions.
Herein, we describe a computational fluid dynamic (CFD) model of a single cell flowing in a microfluidic channel at different conditions. The computational results are then compared with experimental data on HL60 and Jurkat cells on a specific set-up.
Materials and Methods
The cell is modelled as a fluid droplet, where the surface tension represents the membrane tension. A fluid-fluid interaction is solved using the Volume of Fluid (VoF) model in Fluent 16.0 (ANSYS Inc., Canonsburg, PA) for a two-phase flow. Boundary conditions are prescribed that represent both the physiological condition in the microcirculation and the experimental procedure. The setup for the experimental validation is composed of a cross-sectioned microchannel, a syringe pump, a high speed camera (IDT MotionPro Y5) and a plasma source light (HPLS200, ThorLab). Cells are deformed into an elliptical shape by the fluid flow in a specific location of the channel. Image processing is performed with MATLAB2017.
Results and Discussion
The model here presented can represent the behaviour of different cell types, according to the droplet properties. It is possible to identify two different cell behaviours in microcirculation. At low viscosity (0.0045 Pa·s) the cell is deformed into a parachute shape, reaching an equilibrium near the centre of the channel, as typical of Red Blood Cells (RBCs). At high viscosity (100 Pa·s) the cell remains spherical and migrates towards the wall of the channel, as it is characteristic of nucleated cells. The CFD model can accurately represent the experimental data, where HL60 and Jurkat cells can reach values of deformability – distance from the spherical configuration - of 0.025 – 0.05.
Conclusion
In this work, we have used the VoF method to successfully model two different cellular haemodynamic situations, both typical of the microcirculation. The CFD results have been validated with an ad hoc experimental campaign, designed to mechanically stretch and deform single cells.