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# Micro-flow visualization of *in vitro* blood through a microchannel with bifurcation

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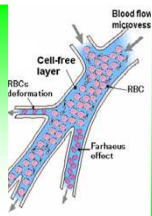
## Introduction

Micro-visualization techniques have been used to investigate in vitro blood flow through straight glass capillaries. Although the glass microchannels present certain similarities to *in vivo* microcirculation, it is also clear that these kind of *in vitro* experiments differ from microvessels in several respects, such as: effect of the endothelial surface layer and microvascular networks composed with short irregular vessel segments which are linked by numerous bifurcations. Thus it was not surprising that several studies on blood flow in glass microtubes and in microvessels have yielded conflicting results with respect to blood viscosity and flow resistance.

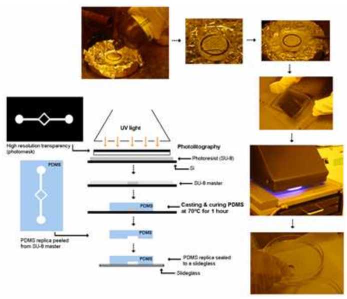



The **main purpose** of this work is to **improve our understanding about the effect of a bifurcation on the rheological properties of *in vitro* blood**. The flow behaviour of both pure water (PW) and dextran40(Dx40) containing about 14%(14Hct) of human red blood cells (RBCs) will be investigated by means of a confocal micro-PTV system. Additionally, the experimental measurements obtained with PW will be also compared numerically by using the commercial finite element software package POLYFLOW®.

## Materials and methods

### Experimental techniques

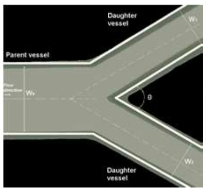
#### Microchannel fabrication



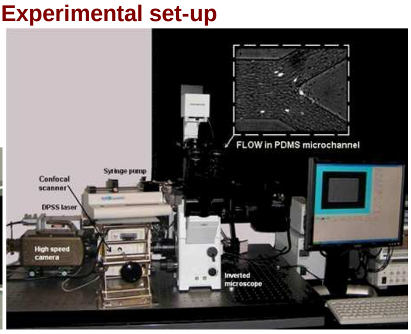

By using a soft lithography the microchannels were made in polydimethylsiloxane (PDMS) due to their advantageous properties, including good optical transparency and biocompatibility, easily reversible sealing to glass, elasticity, replication of fine and complex geometries, and gas permeability which is suitable for culturing cells inside the microchannels.

#### Experimental set-up

Geometry and dimensions of the microchannel bifurcation



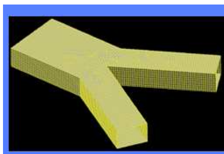

Symmetrical bifurcation geometry : $W_0$ = 150 µm, $W_1$ = $W_2$ = 75 µm, θ = 60º, depth = 50 µm.

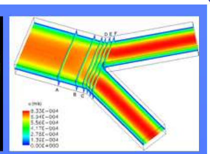



**Experimental parameters**

| | |
|---|---|
| Human RBCs | ≈ 8 µm |
| Fluorescent cell tracker (CM-Dil,C-7000) | |
| Reynolds number | ≈ 0.007 |
| Magnification objective | 32× |
| Capture frame rate | 100 frames/s |

### Simulation method





The numerical calculations for the laminar isothermal flow of pure water were performed using the finite-element computational fluid dynamics (CFD) program POLYFLOW®.

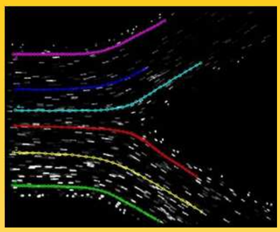
The simulations were carried out in a 3D geometry representing the microchannel.

The mesh used in the simulations was mainly constituted by quadrilateral elements, the discretization of the walls of the channel.

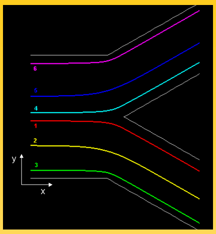
For numerical study, blood was considered Newtonian and non-Newtonian fluid. In the last case, the rheology of blood was described by two different constitutive models: power law model and Carreau model.

## Results and discussion

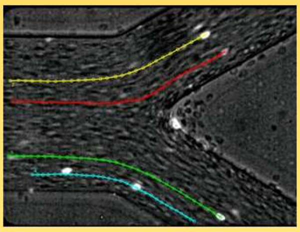
**Paths of fluorescent particles flowing in pure water**



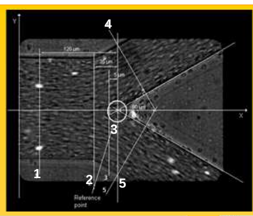
**Numerical trajectories of pure water**



Qualitative comparison between the experimental data from pure water and the numerical simulation shows that in both cases the trajectories do not exhibit any appreciable deviations in the transversal (*yy* axis) direction.

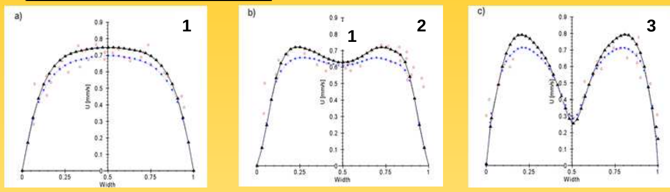


By comparing qualitatively the experimental data from both pure water and *in vitro* blood (14% Hct) it is possible to observe that some RBC paths seems to suffer small deviations from the streamlines of the plasma flow probably due to flow perturbations caused by cell interactions in the neighbourhood of the apex of bifurcation.

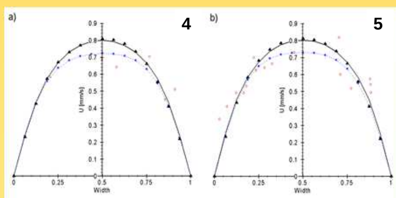



**Experimental and numerical simulations of non-Newtonian models performed around the bifurcation at the regions 1 to 5**

Regions where the velocity profiles of the numerical and experimental results were compared




Velocity profiles for both computational and experimental results before bifurcation: a) region 1; b) region 2; c) region 3. (—) Newtonian; (---) Power Law; (▲) Carreau Model; (□) Confocal micro-PTV RBC velocities.




Velocity profiles after bifurcation: a) region 4; b) region 5; (—) Newtonian; (---) Power Law; (▲) Carreau Model; (□) Confocal.

The RBCs velocities around the microchannel wall are higher than that obtained with the numerical models since slip at the walls of the channel was assumed to be non-existent in the latter case.

It is well know, that in microcirculation the RCBs, tend migrate to the center region of the microchannel and this may explain the observed discrepancies.

## Conclusion and future work

- Qualitative experimental observations suggested that RBC paths around the bifurcation apex seems to suffer small deviations from the streamlines of the plasma flow probably due to cell interactions enhanced by the high local Hct originated at this region.
- The simulations performed with a finite-element CFD program POLYFLOW emphasized the need of developing a multiphase approach.