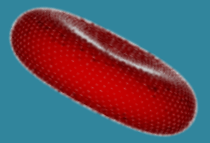

ERYTHROCYTE DEFORMABILITY IN A HYPERBOLIC MICROCHANNEL

Vera Faustino[1], Tomoko Yaginuma[1], Diana Pinho[1,2], Ricardo C. Calhelha[3,4], Isabel C.F.R. Ferreira[4] and Rui Lima[1,2]

[1] *ESTiG, Polytechnic Institute of Bragança, Portugal*
[2] *CEFT, Faculdade de Engenharia, Universidade do Porto, Portugal*
[3] *Centre of Chemistry, University of Minho, Portugal*
[4] *CIMO/ESA, Polytechnic Institute of Bragança, Portugal*

FCT Fundação para a Ciência e a Tecnologia
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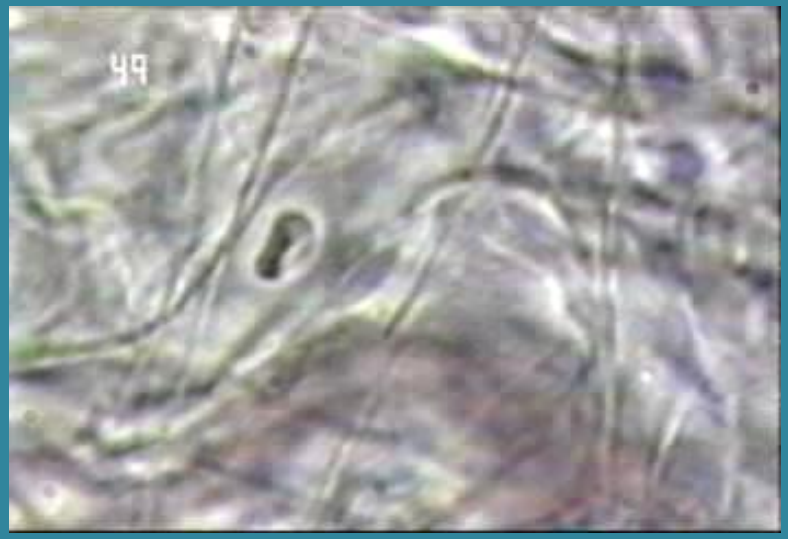
Red Blood Cell (RBC) Deformability

RBC – Highly deformable cell

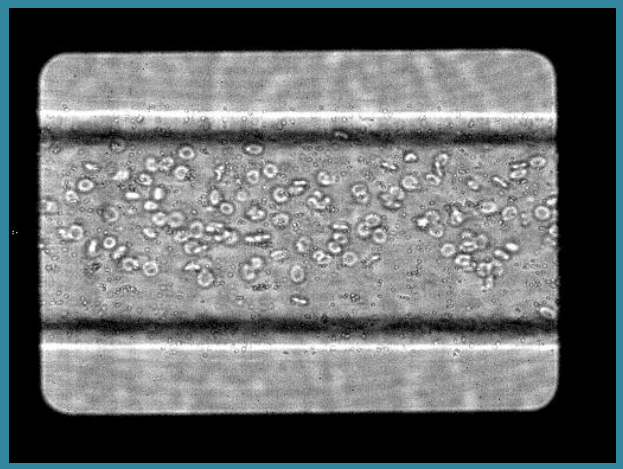
- Important to deliver oxgen to the tissues throughout the body
- Reduced deformability associated with health problems (eg. anemia, diabetes)



Studies on human RBC deformability

Existing studies

- Major focus - Effect of shear flow alone
  - RBC filtration, laser diffraction ellipsometry, rheoscopy, etc.
- Use of straight channels



RBCs under Extensional Flows

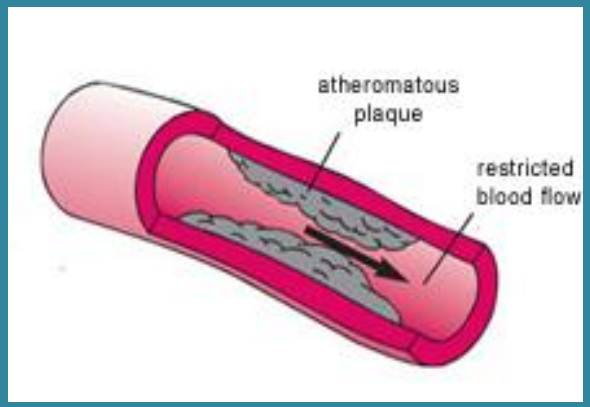
Extensionally-domained flows often found in the human circulatory system

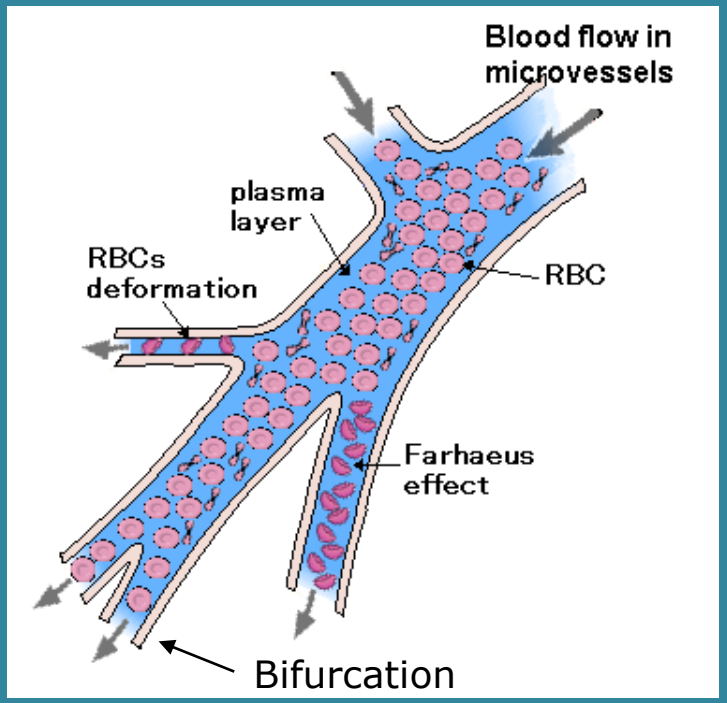
→ A change in the cross-sectional area

→ Bifurcations

→ Stenosis – major problem

in cardiovascular deseases

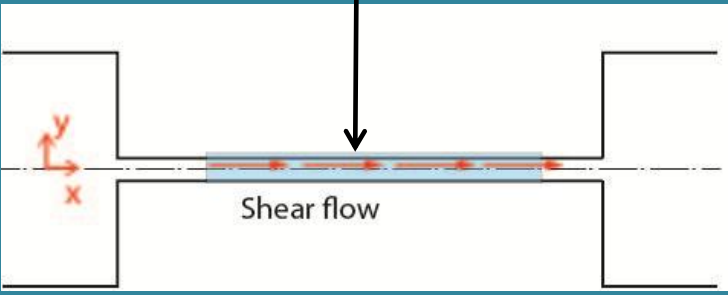




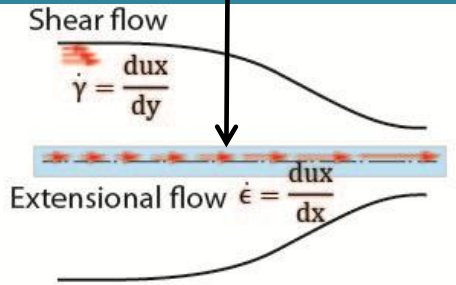
RBC deformability is important.

Shear stress & Extensional stress

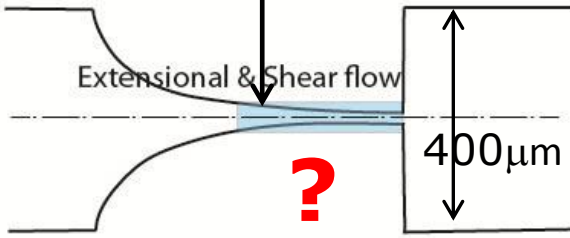
Shear flow study



Extensional flow study



Both shear and extensional flow study

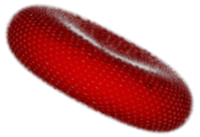


Depth = 14µm

$$\text{Aspect ratio, } AR = \frac{\text{depth}}{\text{width}} = \frac{14}{400} = 0{,}035$$

Low aspect ratio

Objectives

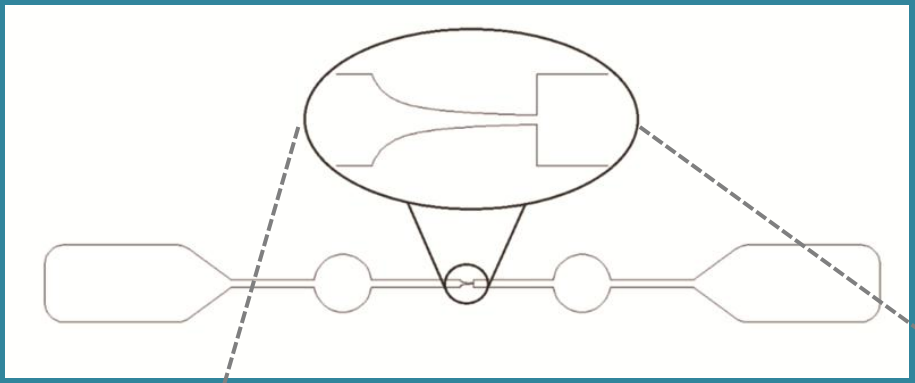


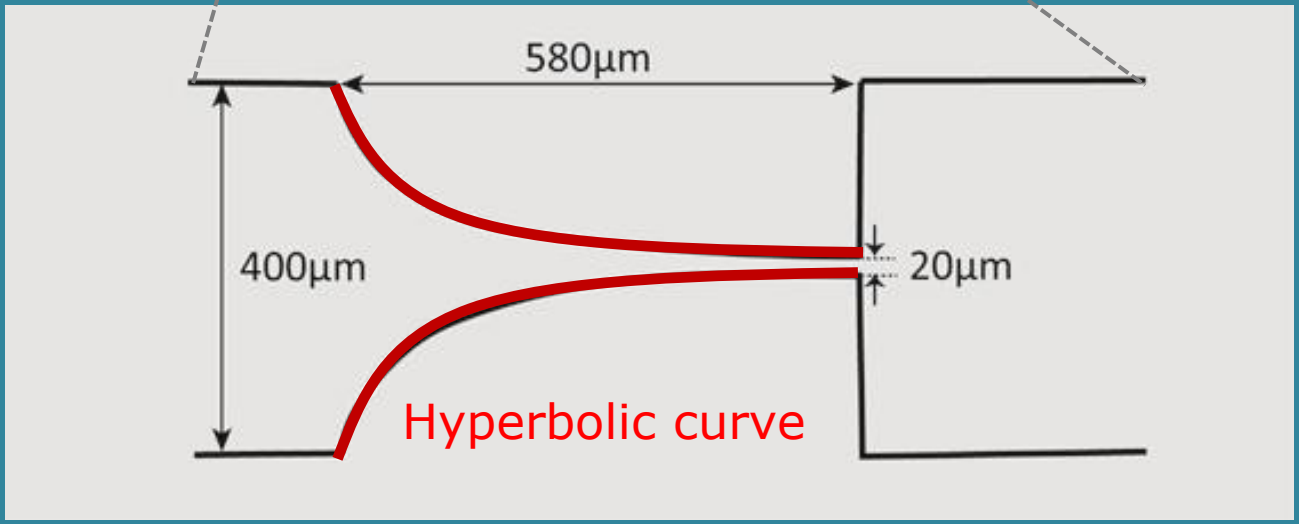
Investigation of the RBC deformation in the both extensional and shear stress dominated flows in a low-aspect ratio hyperbolic microchannel

- Fabrication of Microchannel with Hyperbolic contraction
  - ✓ Geometory for ideal extensional flows
  - ✓ PDMS channel by Softlithography technique
- RBCs deformability measurement – Defomation Index
  - ✓ Experiment set-up – microscopy system with a high speed camera
  - ✓ Image analysis methodology suitable for deformation measurement

Microchannel

Dimensions

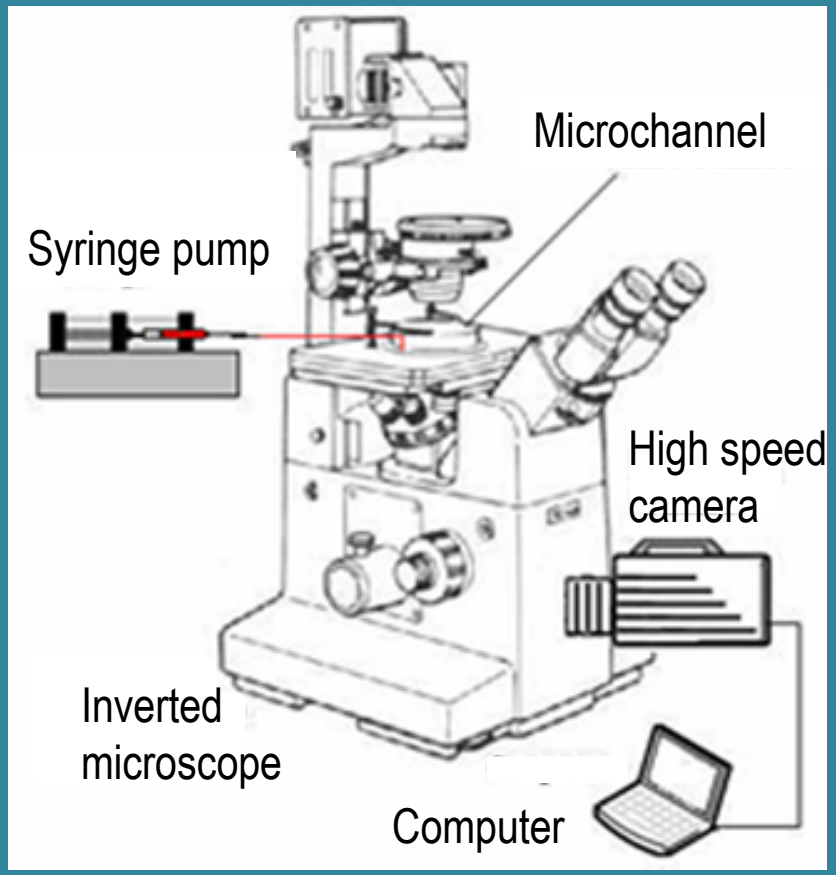




Depth = 14 µm

Experimental set-up

Main components



Experimental parameters

Working fluid	Hank's Balanced Salt Solution (HBSS) containing 2% Hct of Human RBCs
Human RBCs size	≈ 8 µm
Flow rate	0.5µl/min
Frame rate	7500 frames/s

Captured videos to static images

Three separate images and a combined view.

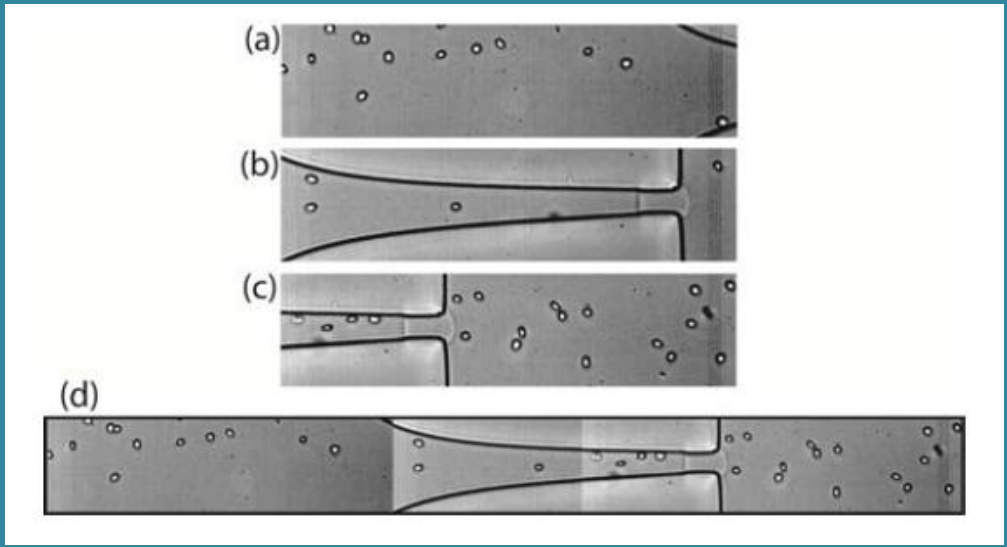
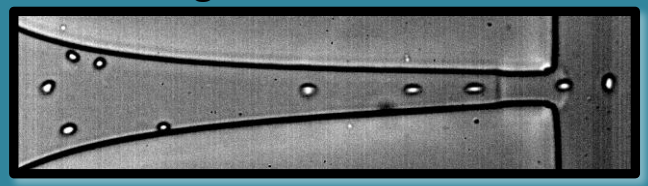


Image Analysis

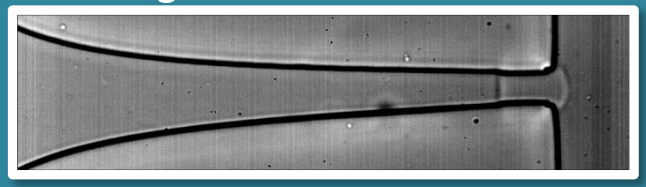
Image filtering by ImageJ

1. Extraction of the cells of interest

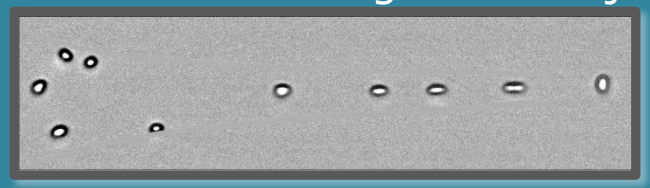
Original



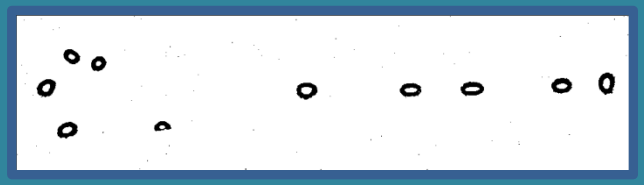
Background "Medium"



Subtracted "Brightness adjustment"

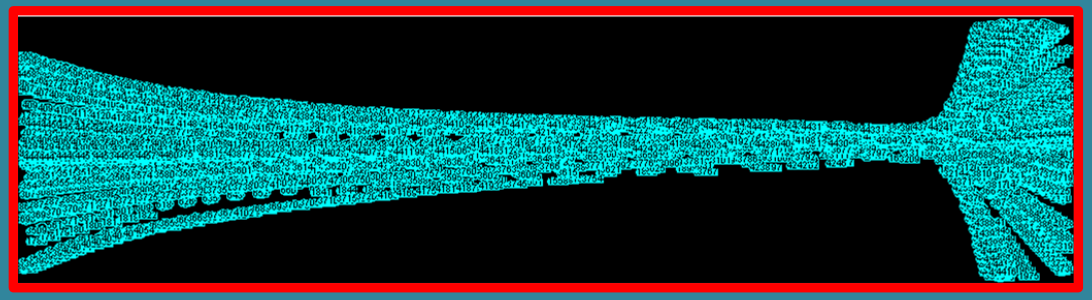


2. Binarization



"Otsu thresholding"

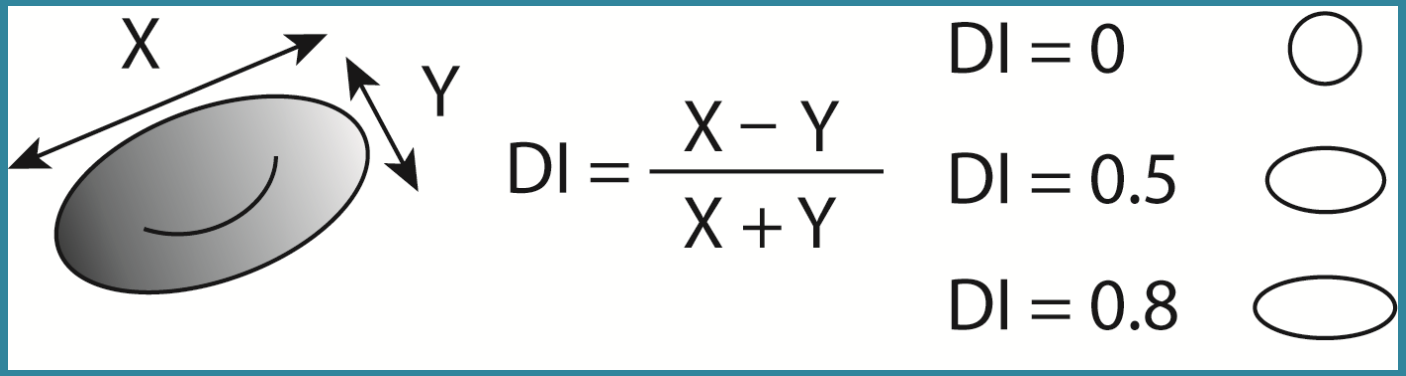
3. RBC Measurement



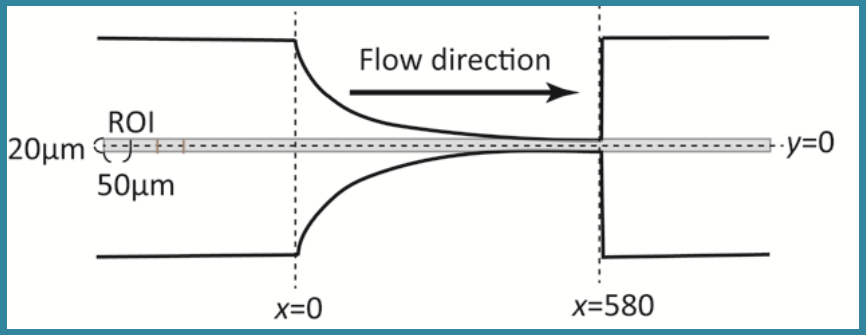
Parameters:
- Area
- Circularity

Deformation Index (DI)

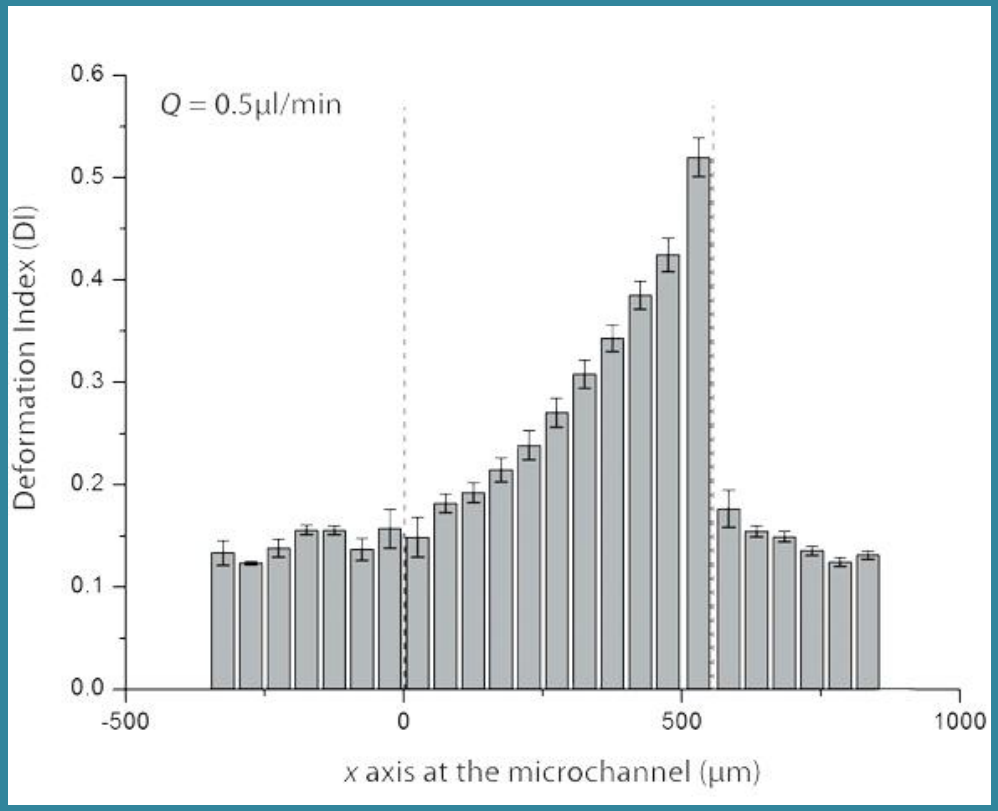
Definition of DI



RBC Deformation Measurement



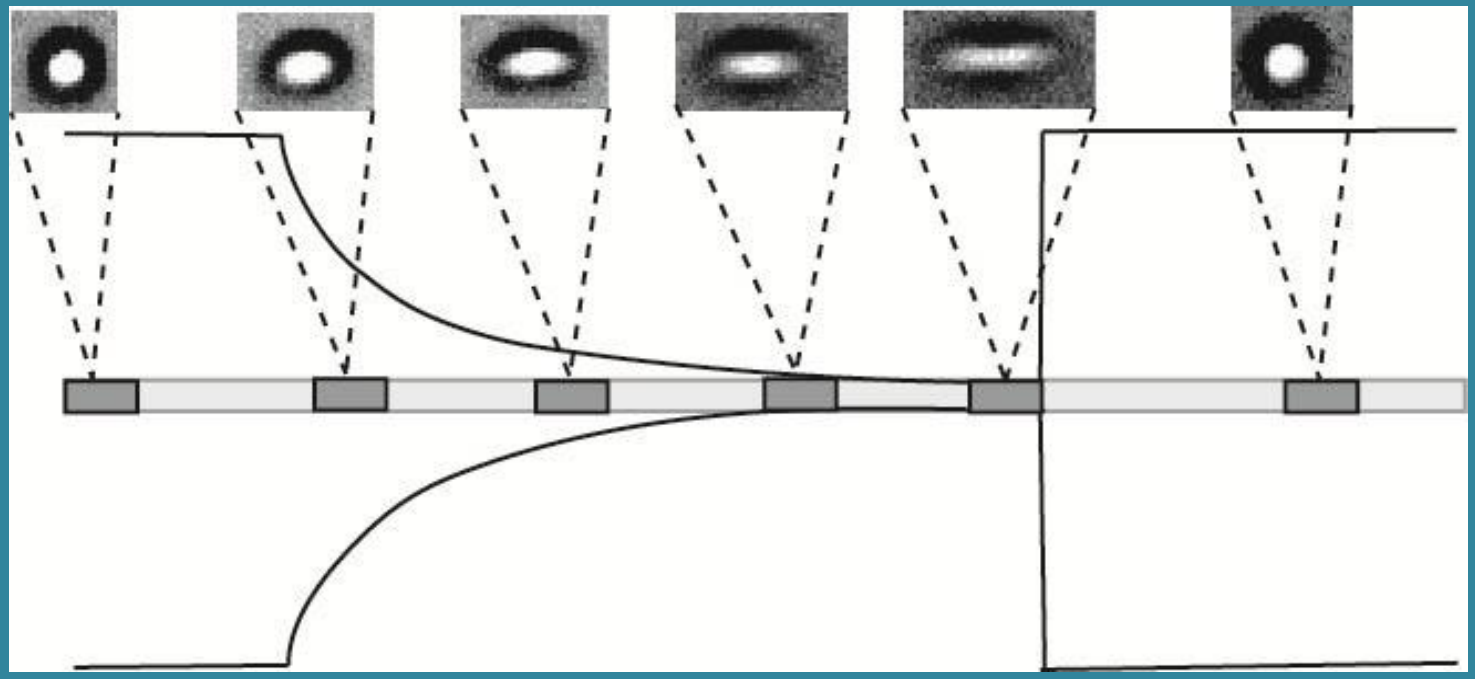
RBCs flowing near the centerline (y=0).



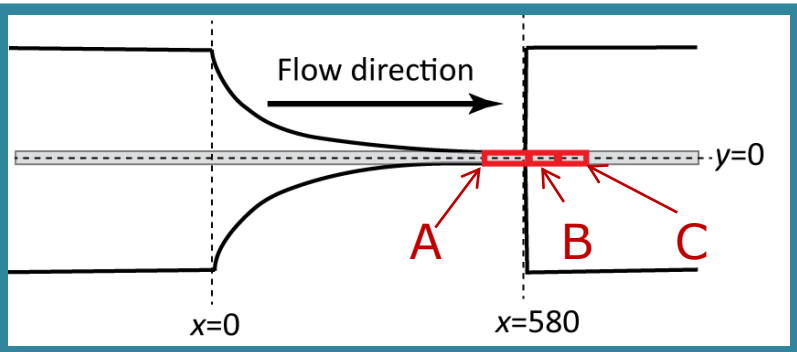
Average of DIs of all ROIs along the centerline.

Highly deformation in contraction region.

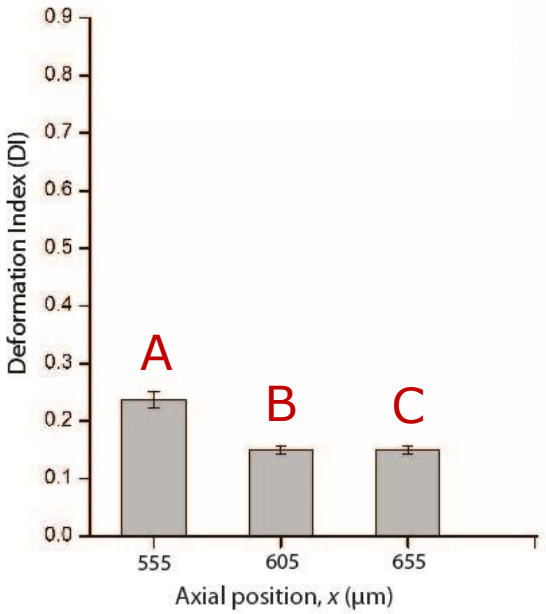
RBC Deformation



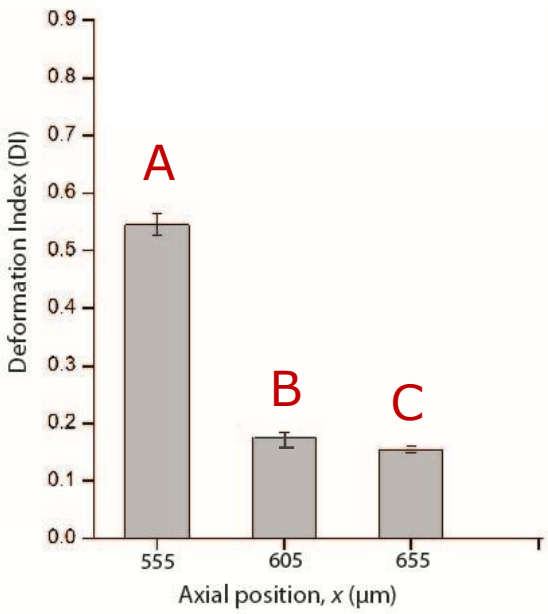
RBC Deformation by Flow Rates



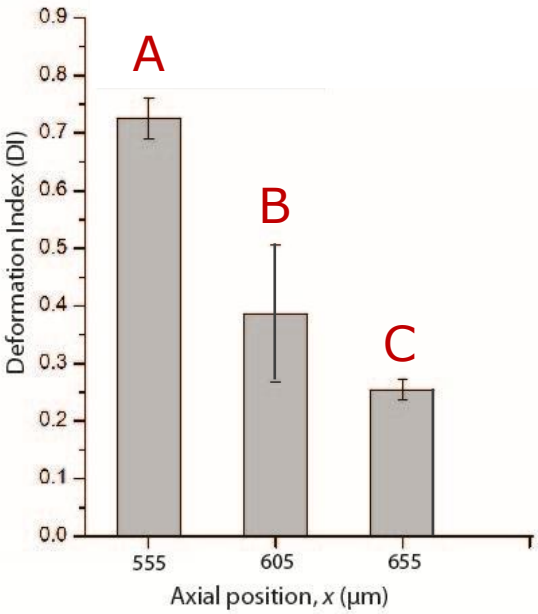
Q = 10nl/min



Q = 500nl/min

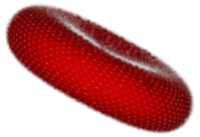


Q = 1000nl/min



DI increases with an increase of flow rate (Q).

Conclusions



RBC Deformation under the extensional and shear flows

- **Higher deformation** in **contraction region**.
- **DI increases** substantially with the **flow rate**, at the contraction region.
- Qualitative analysis indicates stronger deformation in both extensional and shear flows than extensional or shear flow alone.

Acknowledgment

PTDC/SAU-BEB/108728/2008, PTDC/SAU-BEB/105650/2008, SFRH/BPD/68344/2010 and PTDC/SAU-ENB/116929/2010 from the FCT (Science and Technology Foundation), QREN, European Union (FEDER) and COMPETE, Portugal.

MSPS 2012

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Vera Faustino

vera_f_87@hotmail.com