Tohoku University Global COE Programme
"Global Nano-Biomedical Engineering Education and Research Network Centre"
Faculty of Engineering of the University of Porto (FEUP)
Polytechnic Institute of Bragança (ESTiG)

Japan-Portugal Nano-BME Symposium 2011

3 June 2011
Faculty of Engineering of the University of Porto (FEUP)

6 June 2011
Polytechnic Institute of Bragança
(Auditorium Alcino Miguel, ESTiG)

GCOE NanoBME
Tohoku University

FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

ipb INSTITUTO POLITÉCNICO DE BRAGANÇA Escola Superior de Tecnologia e Gestão

Japan-Portugal Nano-BME Symposium 2011

3 June 2011

Faculty of Engineering of the University of Porto (FEUP)

6 June 2011

Polytechnic Institute of Bragança
(Auditorium Alcino Miguel, ESTiG)

Tohoku University Global COE Programme
"Global Nano-Biomedical Engineering Education and Research Network Centre"

Faculty of Engineering of the University of Porto (FEUP)

Polytechnic Institute of Bragança (ESTiG)

GCOE NanoBME Tohoku University

FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

ipb INSTITUTO POLITÉCNICO DE BRAGANÇA Escola Superior de Tecnologia e Gestão

Publication Office

Tohoku University Global COE Programme
Global Nano-Biomedical Engineering Education and Research Network Centre

Department of Biomedical Engineering, Graduate School of Biomedical Engineering, Tohoku University
6-6-01 Aoba, Aoba-ku, Sendai 980-8579, Japan
Tel: +81-22-795-7005 Fax: +81-22-795-5031 E-mail: secretary@nanobme.org
URL: http://www.nanobme.org

ISBN 978-4-904157-20-6

Foreword

It is my greatest pleasure to address the participants of the Japan-Portugal Nano-BME Symposium 2011, set up by University of Porto, Polytechnic Institute of Bragança and Tohoku University. This symposium is sponsored by the Tohoku University Global COE program to promote global activities in the research and higher education. The Tohoku University Global COE Program has promoted nano-biomedical engineering by establishing collaborations between Tohoku University and representative world-wide universities since it began in 2007. A number of successful conferences and meetings have been organized under the umbrella of the GCOE in several countries, and such conferences were proved to be very important to the development of nano- and micro-scale biomedical engineering in the world. In this joint symposium, a number of leading scientists from the University of Porto, Polytechnic Institute of Bragança and Tohoku University will gather to exchange their most recent ideas and the results of cutting edge technologies related to nano- and micro-scale biomedical engineering. This will be an occasion to be remembered in the future, one that sums up and deepens our understanding of research and education in the nano- and micro-scale biomedical engineering fields representing the most rapidly advancing community of science and industry in the 21st century.

As the leader of the Tohoku GCOE program, I would like to welcome all of the participants and I hope that the workshop will be fruitful, not only from a scientific point of view but also in the cultivation of friendships between researchers in Portugal and Japan.

Takami Yamaguchi

Takami Yamaguchi M.D., Ph.D.
Leader
Tohoku University Global COE Program

Foreword

It is our great pleasure to welcome all the participants to the **Japan-Portugal Nano-Biomedical Engineering (BME) Symposium 2011** held at the Faculty of Engineering of the University of Porto (3rd of June, 2011) and at the Polytechnic Institute of Bragança (6th of June, 2011) in Portugal. The aim of this symposium is to be a meeting place where the Japanese and Portuguese academic communities can share new scientific and technical developments in the area of Biomedical Engineering involving phenomena from the macro-scale down to the nano-scale. This year's meeting hosts a variety of themes that range from blood flow in circulatory system to respiratory system, and from heat transfer to artificial neural networks. They also encompass experimental and numerical studies, as well as combinations of both. This diversity is a clear indicator of the quality of the research being carried out by both Portuguese and Japanese research groups, and emphasizes the importance of this type of meeting for an effective knowledge transfer between the two countries.

This symposium is supported by 2007 Tohoku University Global COE Program "Global Nano-Biomedical Engineering Education and Research Network Centre", Polytechnic Institute of Bragança and Transport Phenomena Research Center (CEFT) at the Faculty of Engineering of the University of Porto. We are happy to announce that a total of 17 papers will be presented as either talks or posters. In addition to the contributed papers, we have two outstanding plenary lectures by two prominent speakers, Professor Takami Yamaguchi and Professor Fernando T. Pinho, who are both authorities in their field of expertise. We are grateful to each of them for setting aside their valuable time to participate in this symposium, particularly Professor Yamaguchi who came all the way from Japan to give a presentation.

On behalf of the organization committee, we would like to acknowledge all the authors for their contributions and express our sincere appreciation to the assistance of all parties involved in the organization for their tremendous courage and efforts.

Finally, we hope that **Japan-Portugal Nano-Biomedical Engineering (BME) Symposium 2011** to be a stimulating, profitable and memorable event, and all the attendees will take the opportunity to interact one-on-one with colleagues to advance the field of nano- BME.

Mónica S. N. Oliveira
CEFT, Faculty of Engineering of the University of Porto

Rui Lima
CEFT, Polytechnic Institute of Bragança

Programme

Fri. 3 June 2011 Faculty of Engineering of the University of Porto (FEUP)	
15:00	Opening Remarks
	Keynote Lecture Chair: Rui Lima (Polytechnic Institute of Bragança)
15:10	**Computational Biomechanics for Respiratory and Micro-circulatory Systems** Takami Yamaguchi (Department of Biomedical Engineering, Tohoku University)
	Keynote Lecture Chair: Mónica Oliveira (University of Porto)
15:50	**Transport Phenomena Research Center (CEFT): Research on Complex Flows of Complex Fluids** Fernando T. Pinho (CEFT, DEMec, Faculty of Engineering, University of Porto)
16:30	Adjournment
19:00	Banquet
Mon. 6 June 2011 Polytechnic Institute of Bragança (Auditorium Alcino Miguel, ESTiG)	
14:15	Opening Remarks
	Keynote Lecture Chair: Rui Lima (Polytechnic Institute of Bragança)
14:30	**Computational Biomechanics for Respiratory and Micro-circulatory Systems** Takami Yamaguchi (Department of Biomedical Engineering, Tohoku University)
15:00	Coffee Break
	Session I Chair: Rui Lima (Polytechnic Institute of Bragança) / Mónica Oliveira (University of Porto)
15:15	**Numerical Simulation on Margination of Malaria-infected Red Blood Cells in Microvessels** Yohsuke Imai (Department of Bioengineering and Robotics, Tohoku University)
15:30	**Analysis of Ciliary Motion and Fluid Flow on the Surface of Tracheal Cells** Hironori Ueno (International Advanced Research and Education Organization (IAREO), Tohoku University)
15:45	**Numerical Simulation of Cell Depleted Peripheral Layer and Red Blood Cells Motion in Microvascular Blood Flow** Davod Alizadehrad (Department of Biomedical Engineering, Tohoku University)
16:00	**Gradient Diffusion of Red Blood Cells in a Y-shape Microchannel** Cheng-Hsi Chuang (Department of Biomedical Engineering, Tohoku University)
16:15	**High Performance GPU Computing of Capsule Flow using Boundary Integral Method** Daiki Matsunaga (Department of Bioengineering and Robotics, Tohoku University)
16:30	Coffee Break/ Poster Session

	Session II Chair: Yohsuke Imai (Tohoku University)
17:30	**A Numerical Study on the Cooling Power of an Enhanced Convection Solution for Footwear** Tiago S. Mayor (Centre for Nanotechnology and Smart Materials (CeNTI))
17:45	**Flow of a Blood Analogue Solution through Microchannels with Bifurcations** Patrícia C. Sousa (CEFT, DEQ, Faculty of Engineering, University of Porto)
18:00	**Motions of Trace Particles and Red Blood Cells in a PDMS Microchannel with a Converging Bifurcation** Vladimir Leble (ESTiG, Polytechnic Institute of Bragança)
18:15	**Tracking Erythorcytes in a 100 µm Glass Capillary** Diana Pinho (ESTiG, Polytechnic Institute of Bragança)
18:30	**Classification of Alzheimer's Electroencephalograms using Artificial Neural Networks and Logistic Regression** Pedro Rodrigues (ESTiG, Polytechnic Institute of Bragança)
18:45	Adjournment

Poster Session

Flow of Red Blood Cells in Capillary Networks
Ana Couto/Lúcia Teixeira (Polytechnic Institute of Bragança)

Analysis of the Cell-Free Layer in a Circular Microchannels: Trajectories of Labeled Red Blood Cells
Catarina Meireles (Polytechnic Institute of Bragança)

Synthesis of Magnetic Iron Oxide Nanoparticles for Biomedical Applications
Cidália Gomes/Luís Veiga (Polytechnic Institute of Bragança)

Production of Chitosan Based Films Enriched with Essential Oils for Biomedical Applications
Diana Vilas-Boas/Erica Leite (Polytechnic Institute of Bragança)

Experimental and Numerical Characterization of Displacement Field on Biological Tissues
João Ribeiro (Polytechnic Institute of Bragança)

Dynamic Sedimentation Measurements of Physiological Fluids in Biomedical Devices
Valdemar Garcia (Polytechnic Institute of Bragança)

Development of a Microfluidic Device for Partial Cell Separation
Rui Lima/Mónica Oliveira (Polytechnic Institute of Bragança)

Dynamic Sedimentation Measurements of Physiological Fluids in Biomedical Devices

Valdemar Garcia[1], Teresa Correia[1), 2)], Ricardo Dias[1), 3)], and Rui Lima[*1), 3)]

1) ESTiG/IPB, Instituto Politécnico de Bragança, Bragança, Portugal
2) CIMO, ESA, Instituto Politécnico de Bragança (IPB), Bragança, Portugal.
3) CEFT, Faculdade de Engenharia da Universidade do Porto, Porto, Portugal.
E-mail: ruimec@ipb.pt

Abstract

In this experimental work we investigate the flow of two different physiological fluids frequently used in microfluidic devices: physiological saline (PS) and dextran 40 (Dx40) containing about 6% of sheep red blood cells (RBCs), respectively. The capillaries were placed horizontally on a slide glass and the flow rate of the working fluids was kept constant. Images were obtained and analysed. Generally, the results show that PS and Dx40 have different flow behaviour due to the sedimentation of the RBCs.

1. Introduction

Currently, biomedical microdevices are becoming one of the most promising tools for the diagnostic and treatment of several diseases, such as diabetes, malaria and cancer. Hence, it is increasingly important to investigate the rheological behaviour of physiological fluids in microchannels in order to make use on the physics of microfluidics to either develop new lab-on-chip devices or to optimize the design of the existent microfluidic chips [1-3]. In this work we investigated the flow behaviour of two different physiological fluids frequently used in biomedical microdevices. By using a syringe pump and a camera it was possible to measure qualitatively the flow behaviour within a horizontal capillary.

2. Materials and Methods

2.1. Blood sample preparation

Two working fluids were used in this study: physiological saline (PS) containing about 6% (6Hct) of sheep red blood cells (RBCs), dextran 40 (Dx40; Otsuka Medicine) containing about 6% (6Hct) of sheep RBCs. The blood was collected from a healthy adult sheep, where heparin was added to prevent coagulation. The RBCs where separated from the bulk blood by centrifugation (3000 RPM for 15 min) and aspiration of the plasma and buffy coat and then washed twice with PS. The washed RBCs where diluted with PS to make up the required RBCs concentration by volume. The hematocrit (Hct) of the RBCs suspension sample was about 6% (6Hct). All the blood samples were stored hermetical at 4°C until the experiment was performed at room temperature (18 to 20°C). Fig. 1 shows the main steps for the preparation of the blood samples.

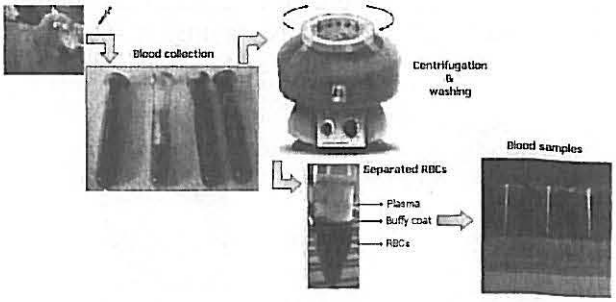
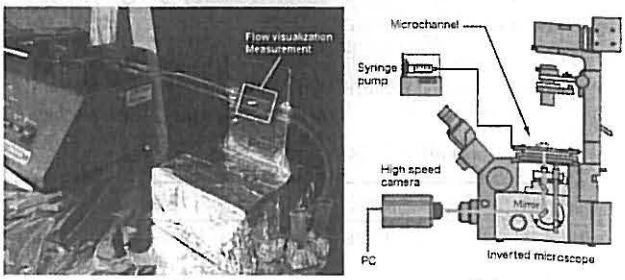


Fig. 1. Main steps for the preparation of the blood samples.

2.2. Experimental setup

To investigate the RBC dynamic sedimentation we used two capillaries placed horizontally on a slide glass and by using a syringe pump (New Era Pump Systems, USA) a pressure-driven flow was kept constant at 50 µl/min which corresponds to a Reynolds ~0.9 (PS) and ~0.3 (Dx40) (see Fig.2a). Additionally the visualization of the flow in microchannels was possible by means of a high-speed video microscopy system (see Fig.2b). More information about this microvisualization system can be found elsewhere [4-6].



(a) (b)

Fig. 2 (a) Experimental setup for the dynamic sedimentation measurements, (b) visualization of the in vitro blood flow in glass microchannels (adapted from 4, 6).

3. Results and Discussion

To analyse the dynamic sedimentation of PS and Dx40 containing RBCs we decided to use flow rates

close to the one observed *in vivo*, i.e., 10 μl/min. During the experiment we made flow qualitative visualizations measurements in glass tubes with diameters of about 1.2 mm. The visualizations were captured by a camera for about 15 minutes. Fig. 3 shows the flow qualitative measurements for 0 minutes and 15 minutes. This image shows clearly that for a period of 15 minutes the RBC tend to settle down in the fluid with PS whereas using Dx40 we did not observe any RBC sedimentation. Although not shown in Fig. 3, for the case of PS fluid we did not observe any RBC sedimentation for the first 10 minutes. According to our visualization the RBCs tend to settle down for period of time superior to 10 minutes.

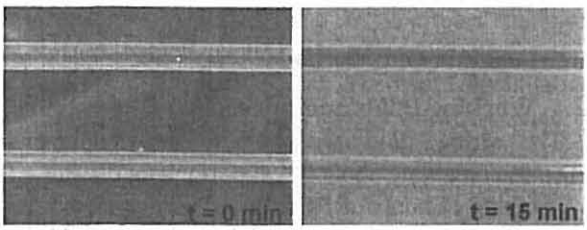


Fig. 3. Dynamic sedimentation measurements for two time periods of PS and Dx40 containing RBCs (Flow rate = 50 μl/min).

Flow visualization measurements were also performed in glass microchannels (see Fig.4) and compared with *in vivo* blood flow (see Fig.5). Fig. 4 shows that for the case of Dx40 there is a clear formation of cell-free layer (CFL) adjacent to the walls of microchannels. However, in the fluid with PS the RBCs do not exhibit a clear tendency to migrate into the microtube axis. The *in vivo* visualization measurements (Fig. 5) have shown a clear tendency for the formation of a plasma layer in microvessels [6, 7].

In conclusion, these results indicate that *in vitro* blood containing Dx40 has a flow behaviour closer to the one observed *in vivo* microvessels. The *in vitro* blood containing PS did not show a clear formation of CFL which might be due to the fast sedimentation of the RBCs. In the near future we plan to vary the flow rate and diameter to study the influence of these effects on the RBC sedimentation.

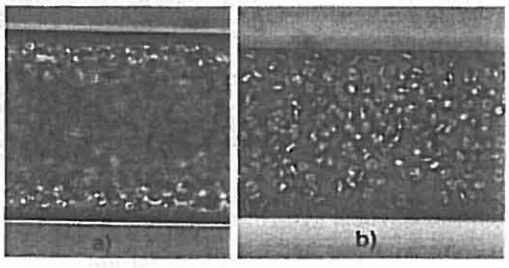


Fig. 4. Flow of RBCs in capillaries for a period time bigger than 10 minutes a) Dx40 containing RBCs; b) PS containing RBCs.

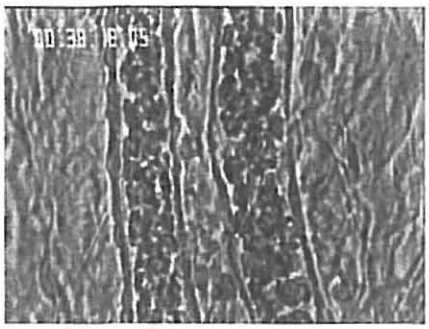


Fig. 5. I*n vivo* flow visualization in a microvessel. [7].

Acknowledgements

This study was supported in part by the following grants: Grant-in-Aid for Science and Technology (PTDC/SAU-BEB/108728/2008 and PTDC/SAU-BEB/105650/2008) from the Science and Technology Foundation (FCT) and COMPETE, Portugal.

References

[1] Lima R, Ishikawa T, *et al.* Blood flow behavior in microchannels: advances and future trends. Single and two-Phase Flows on Chemical and Biomedical Engineering. Bentham, 2011 (in press).

[2] Goldsmith H and Turitto V. Rheological aspects of thrombosis and haemostasis: basic principles and applications. ICTH-Report-Subcommittee on Rheology of the International Committee on Thrombosis and Haemostasis. *Thromb Haemost.* **55**, 3, 415–435, 1986.

[3] Maeda N. Erythrocyte rheology in microcirculation. *Japanese Journal of Physiology* **46**, 1-14, 1996.

[4] Lima R, Wada S, Tsubota K, and Yamaguchi T. Confocal micro-PIV measurements of three dimensional profiles of cell suspension flow in a square microchannel. *Measurement Science and Technology* **17**, 797-808, 2006.

[5] Lima R, Ishikawa T, Imai Y, Takeda M, Wada S, and Yamaguchi T. Measurement of individual red blood cell motions under high hematocrit conditions using a confocal micro-PTV system. *Annals of Biomedical Engineering*. **37**, 1546-59, 2009.

[6] Kim S, Kong, R L, *et al.* A computer-based method for determination of the cell-free layer with in microcirculation. *Microcirculation* **13**, 199-207, 2006.

[7] Minamiyama M, In Vivo Microcirculatory Studies. [Online] http://www.ne.jp/asahi/minamiya/medicine/ [2000].