fluids

MDPI

Editorial

Experimental and Numerical Studies in Biomedical Engineering

Spiros V. Paras [1,*] and Athanasios G. Kanaris [2]

[1] Department of Chemical Engineering, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
[2] Scientific Computing Department, Rutherford Appleton Laboratory, Didcot OX11 0QX, UK; agkanaris@gmail.com
* Correspondence: paras@auth.gr; Tel.: +30-2310-996-174

Received: 3 June 2019; Accepted: 5 June 2019; Published: 6 June 2019

check for updates

Keywords: microfluidics; blood flow; viscoelastic; falling film microreactor; μ-PIV; abdominal aortic aneurysm; hematocrit; computational fluid dynamics simulations; fluid–structure interaction; arterial wall shear stress; drug delivery; droplet spreading; passive trapping; cell capture; lab-on-a-chip; physiology-based biokinetics; liposomes; shikonin; human bio-monitoring

The term "biomedical engineering" refers to the application of the principles and problem-solving techniques of engineering to biology and medicine. Biomedical engineering is an interdisciplinary branch, as many of the problems health professionals are confronted with have traditionally been of interest to engineers because they involve processes that are fundamental to engineering practice. Biomedical engineers employ common engineering methods to comprehend, modify, or control biological systems, and to design and manufacture devices that can assist in the diagnosis and therapy of human diseases.

The goal of this Special Issue of *Fluids* is to be a forum for scientists and engineers from academia and industry to present and discuss recent developments in the field of biomedical engineering. It contains papers that tackle, both numerically (computational fluid dynamics studies) and experimentally, biomedical engineering problems, with a diverse range of studies focusing on the fundamental understanding of fluid flows in biological systems, modelling studies on complex rheological phenomena and molecular dynamics, design and improvement of lab-on-a-chip devices, modelling of processes inside the human body, and drug delivery applications. Contributions have focused on problems associated with subjects that include hemodynamical flows, arterial wall shear stress, targeted drug delivery, fluid–structure interaction/computational fluid dynamics (FSI/CFD) and multiphysics simulations, molecular dynamics modelling, and physiology-based biokinetic models.

In a comprehensive computational modelling study focused on complex rheological phenomena, Alexopoulos and Kiparissides [1] are using a macroscopic model to investigate the spreading of a linear viscoelastic fluid with changing rheological properties over flat surfaces. The computational model is based on a macroscopic mathematical description of the gravitational, capillary, viscous, and elastic forces. The dynamics of droplet spreading are determined in sessile and pendant configurations for different droplet extrusion or formation times for a hyaluronic acid solution undergoing gelation. The computational model is employed to describe the spreading of hydrogel droplets for different extrusion times, droplet volumes, and surface/droplet configurations. The effect of extrusion time is shown to be significant in the rate and extent of spreading.

In a series of studies where microfluidics engineering principles are used to improve understanding of biomedical phenomena, Paras and Mouza with their group contribute three different papers under this common theme:

Koupa et al. [2] present a study of the geometrical characteristics of a free-flowing non-Newtonian shear-thinning fluid flowing in an inclined open microchannel. The liquid film characteristics were

measured by a non-intrusive technique that is based on the features of a micro particle image velocimetry (μ-PIV) system. Relevant computational fluid dynamics (CFD) simulations revealed that the volume average dynamic viscosity over the flow domain is practically the same as the corresponding asymptotic viscosity value, which can thus be used in the proposed design equations. A generalized algorithm for the design of falling film microreactors (FFMRs), containing non-Newtonian shear thinning liquids is also proposed.

Mouza et al. [3] present a simplified model for predicting friction factors of laminar blood flow in small-caliber vessels. The aim is to provide scientists with a correlation that can assist with the prediction of pressure drop that arises during blood flow in small-caliber vessels. This study has been conducted, like the previous one, using a combination of CFD simulations validated with relevant experimental data, acquired by the group. Experiments relate the pressure drop measurement during the flow of a blood analogue that follows the Casson model, that is, an aqueous glycerol solution that contains a small amount of xanthan gum. Results from this study lead to the proposal of a simplified model that incorporates the effect of the blood flow rate, the hematocrit value (35–55%) and the vessel diameter (300–1800 μm) and predicts, with satisfactory accuracy, pressure drop during laminar blood flow in healthy small-caliber vessels.

Stergiou et al. [4] in their contribution incorporated a complex multiphysics simulation to provide a realistic model of blood flow and to numerically examine, using a fully coupled fluid–structure interaction (FSI) method, the complicated interaction between the blood flow and the abdominal aortic aneurysm (AAA) wall. The study investigates the possible link between the dynamic behavior of an AAA and the blood viscosity variations attributed to the haematocrit value, while it also incorporates the pulsatile blood flow, the non-Newtonian behavior of blood and the hyperelasticity of the arterial wall. Results in terms of wall shear stress (WSS) show that its fluctuations due to haematocrit changes can alter the mechanical properties of the arterial wall and increase the growth rate of the aneurysm or even its rupture possibility.

In the field of drug delivery, Tsermentseli et al. [5] present a comparative study between PEGylated and conventional liposomes, as carriers for shikonin. Liposomes are considered one of the most successful drug delivery system. On the other hand, shikonin and alkannin, a pair of chiral natural naphthoquinone compounds, are widely used due to their various pharmacological activities. The study reports the effects of different lipids and polyethylene glycol (PEG) on parameters related to particle size distribution, polydispersity index, ζ-potential, drug-loading efficiency and stability of the prepared liposomal formulations. Three types of lipids were assessed (DOPC, DSPC, DSPG), separately and in mixtures, forming anionic liposomes with good physicochemical characteristics, high entrapment efficiencies, satisfactory in vitro release profiles, and good physical stability. The shikonin-loaded PEGylated sample with DOPC/DSPG, demonstrated the most satisfactory characteristics and is considered promising for further design and improvement of these type of formulations.

In the field of lab-on-a-chip research, Narayanamurthy et al. [6] present a study on pipette Petri dish single-cell trapping (PP-SCT) as an application of a passive hydrodynamic technique. PP-SCT is simple and cost-effective with ease of implementation for single cell analysis applications. In their study, passive microfluidic-based biochips capable of vertical cell trapping with the hexagonally-positioned array of microwells are exhibited and a wide operation at different fluid flow rates of this novel technique is demonstrated. Using human lung cancer cells, single-cell capture (SCC) capabilities of the microfluidic-biochips are found to be improving from the straight channel, branched channel, and serpent channel, accordingly. Multiple cell capture (MCC) is on the order of decreasing from the straight channel, branch channel, and serpent channel. Among the three designs investigated, the serpent channel biochip offers high SCC percentage with reduced MCC and NC (no capture) percentage. Using the PP-SCT technique, flow rate variations can be precisely achieved.

In a study focusing on the use of physiology-based biokinetic (PBBK) models, Sarigiannis and Karakitsios [7] aim at the development of a lifetime PBBK model that covers a large chemical space, which, when coupled with a framework for human biomonitoring (HBM) data assimilation, provides

an advanced chemical risk assessment method. The methodology developed was demonstrated in the case of bisphenol A (BPA), where exposure analysis was based on European HBM data. Based on their calculations, it was found that current exposure levels in Europe are below the temporary tolerable daily intake (t-TDI) proposed by the European Food Safety Authority (EFSA). The authors propose refined exposure metrics, which show that environmentally relevant exposure levels are below the concentrations associated with the activation of biological pathways relevant to toxicity.

Finally, in a computational study using molecular dynamics (MD), Arsenidis and Karatasos [8] present fully atomistic MD simulations employed to study the interactions between a complex comprised by a PEGylated hyperbranched polyester (HBP) and doxorubicin molecules, with a model membrane in an aqueous environment. The effects of the presence of the lipid membrane in the drug molecules' spatial arrangement are examined in detail and the nature of their interaction with the latter are discussed and quantified where possible. A partial migration of the drug molecules towards the membrane's surface takes place, while clustering behavior of the drug molecules appeared to be enhanced in the presence of the membrane, and development of a charge excess close to the surface of the hyperbranched polymer and of the lipid membrane is observed. The build-up of the observed charge excesses, together with the changes in the diffusional behavior of the drug molecules are of particular interest, regarding the latest stages of the liposomal disruption and the release of the cargo at the targeted sites.

We would like to thank the contributors to this Special Issue for sharing their research, and the reviewers for generously donating their time to select and improve the manuscripts.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Alexopoulos, A.H.; Kiparissides, C.A. Computational Model for the Analysis of Spreading of Viscoelastic Droplets over Flat Surfaces. *Fluids* **2018**, *3*, 78. [CrossRef]
2. Koupa, A.T.; Stergiou, Y.G.; Mouza, A.A. Free-Flowing Shear-Thinning Liquid Film in Inclined μ-Channels. *Fluids* **2019**, *4*, 8. [CrossRef]
3. Mouza, A.A.; Skordia, O.D.; Tzouganatos, I.D.; Paras, S.V. A Simplified Model for Predicting Friction Factors of Laminar Blood Flow in Small-Caliber Vessels. *Fluids* **2018**, *3*, 75. [CrossRef]
4. Stergiou, Y.G.; Kanaris, A.G.; Mouza, A.A.; Paras, S.V. Fluid-Structure Interaction in Abdominal Aortic Aneurysms: Effect of Haematocrit. *Fluids* **2019**, *4*, 11. [CrossRef]
5. Tsermentseli, S.K.; Kontogiannopoulos, K.N.; Papageorgiou, V.P.; Assimopoulou, A.N. Comparative Study of PEGylated and Conventional Liposomes as Carriers for Shikonin. *Fluids* **2018**, *3*, 36. [CrossRef]
6. Narayanamurthy, V.; Lee, T.P.; Khan, A.Y.F.; Samsuri, F.; Mohamed, K.; Hamzah, H.A.; Baharom, M.B. Pipette Petri Dish Single-Cell Trapping (PP-SCT) in Microfluidic Platforms: A Passive Hydrodynamic Technique. *Fluids* **2018**, *3*, 51. [CrossRef]
7. Sarigiannis, D.; Karakitsios, S. Advancing Chemical Risk Assessment through Human Physiology-Based Biochemical Process Modeling. *Fluids* **2019**, *4*, 4. [CrossRef]
8. Arsenidis, P.; Karatasos, K. Computational Study of the Interaction of a PEGylated Hyperbranched Polymer/Doxorubicin Complex with a Bilipid Membrane. *Fluids* **2019**, *4*, 17. [CrossRef]