Mathematical modelling and parameter estimation of Organ-on-chips (OOC)

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Abstract

Recent developments in laboratory experiments have been made on Organs-on-Chips (OOC). These are microfluidic chip envirionments, where the cultivation of multiple cell species, such as immune cells and tumor cells, is possible.
Inspired by laboratory experiments, a mathematical model is derived which is based on coupled reaction-diffusion-transport equations with different chemotactic functions that are able to describe a variety of different cell mechanics and takes into account the possibility of drug administration for drug testing effects.

Our effort is devoted to the development of a simulation tool that is not only able to reproduce the chemotactic movement and the interaction between different cell species living in the microfluidic chip environment but also to use real data obtained from the laboratory experiments to estimate the model parameters and infer the most plausible chemotactic function present in the experiment.

The main issues faced in this work are divided into the proper derivation of the mathematical model and the efficent calibration of the model against real data. For the former, we introduce mass-preserving and positivity-preserving conditions, involving the balancing of incoming and outgoing fluxes passing through the interfaces between 2D and 1D domains of the chip and the development of mass-preserving positivity preserving numerical conditions at the external boundaries and at the interfaces between 2D and 1D domains. For the latter, the real data, mostly available as microscopic data in form of cell trajectories, first needs to be transformed into macroscopic density data. Afterwards it can be used in the calibration algorithm based on minimization methods which applies several techniques such as regularization terms and multigrids application to improve the results.

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