The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

A Multiscale and Multiphase, Data- and Knowledge-Driven Simulation of Function-Perfusion Processes in the Human Liver

Lena Lambers[*,1,2], **Steffen Gerhäusser**[1], **Luis Mandl**[1], **André Mielke**[1] **and Tim Ricken**[1]

[1] Institute of Mechanics, Structural Analysis and Dynamics, Faculty for Aerospace Engineering and Geodesy, University of Stuttgart, Pfaffenwaldring 27, 70569 Stuttgart, lena.lambers@isd.uni-stuttgart.de, https://www.isd.uni-stuttgart.de

[2] Experimental Transplantation Surgery, Department of General, Visceral and Vascular Surgery, Jena University Hospital, Jena, Germany

Keywords: *Multiscale, Multiphase, TPM, Liver, Data-Driven, Continuum Biomechanics*

Modeling active biological systems, such as the human liver, with a complex interaction between cellular metabolism and perfusion in the functional units, requires a multiscale and multiphase approach to the tissue. Changes in hepatic perfusion and tissue morphology induced by surgical interventions or liver disease, directly influence the coupled liver function [1]. To better understand the interplay between hepatic perfusion, metabolism and tissue in the hierarchically organized liver structure, we have developed a multicomponent, poro-elastic multiphase and multiscale function-perfusion model, cf. [2], using a multicomponent mixture theory based on the Theory of Porous Media (TPM, see [3]). The multiscale approach considers the different functional units of the liver, the so-called liver lobules, with an anisotropic blood flow, and the hepatocytes, where the biochemical metabolic reactions take place. On the lobular scale, we assume a homogenized tetraphasic mixture body, composed of a porous solid structure representing healthy tissue, a liquid phase describing the blood, and two solid phases with the ability of growth and depletion representing the fat and the tumor tissue. The phases consist of a carrier phase, called solvent, and solutes, representing microscopic components dissolved in the solvent. To describe the metabolic processes in the cells, the describing PDEs on the lobule scale are coupled with ODEs on the cell scale, resulting in a bi-scale PDE-ODE approach.

To enable patient-specific simulations and increase the robustness of the model, data-driven approaches will be implemented for computationally critical parts of the model. We use experimental, clinical and in silico data such as stained histological liver sections, perfusion measures or imaging data [4] for parametrization and validation of the multiphase model. The overarching goal is to define and develop an accurate decision-supporting framework for clinical applications.

REFERENCES

[1] Christ, B., [...], Lambers, L., [...] Ricken, T., et al. *Frontiers in Physiology* (2021) **12**

[2] Ricken, T., et al. *Biomech Model Mechanobiol* (2015) **14**:515–536

[3] Ehlers, W. *Foundations of multiphasic and porous materials* (2002)

[4] Seyedpour, S. M., [...], Lambers, L., [...] and Ricken, T. *Frontiers in Physiology* (2021) **12**