IMAGING AND MODELLING THE BLOOD CIRCULATION THROUGH THE LIVER AND KIDNEY

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ABSTRACT

Introduction: The blood circulation through the liver and kidney plays a crucial role in organ (dys)function, disease, surgery, transplantation etc. However, the hepatic and renal vasculature and perfusion are complex and not fully understood. It is thus essential to further explore their angioarchitecture and hemodynamics. To this end, we imaged and modelled the blood flow through the liver and kidney across different length scales.

Methods and results: A combination of vascular corrosion casting, micro-CT scanning (up to a 2.6 μm resolution) and image processing led to detailed 3D reconstructions of the angioarchitecture of human and rat livers as well as human and pig kidneys. Subsequently, the geometrical features (branching topology, radii, lengths…) of the vascular trees could be analysed from the macro- (Fig. 1a-b) down to the microvascular level (Fig. 1c) [1].
Based on the macrocirculation data (Fig. 1a-b), whole organ electrical analog models of the blood circulation through the liver and kidney were developed. This allows simulating pressure drops and flows throughout the vasculature for different boundary conditions (e.g. natural blood flow, machine perfusion) [1].
At the microlevel, hepatic perfusion characteristics were investigated using computational fluid dynamics (CFD) modelling. 3D reconstructions of the human liver microstructure (Fig. 1c) were used to numerically simulate the blood flow through sinusoids (liver-specific capillaries), revealing anisotropic permeability characteristics in liver lobules (higher permeability parallel to the central vein; lower permeability in radial and circumferential directions). These results were incorporated in a 3D porous medium liver lobule model, which illustrated the importance of vascular septa for a homogeneous flow distribution [1].

Conclusion: A multilevel imaging and modelling approach was developed to simulate organ blood perfusion at different length scales. Unique 3D morphological and geometrical data have been obtained from the macrocirculation down to the microcirculation level, as well as novel models and insights into the hemodynamic behavior of the liver and kidney. The presented methodology is also applicable to other tree-like structures (e.g. the biliary tree), organs (e.g. lungs) and conditions (e.g. diseases such as cirrhosis).

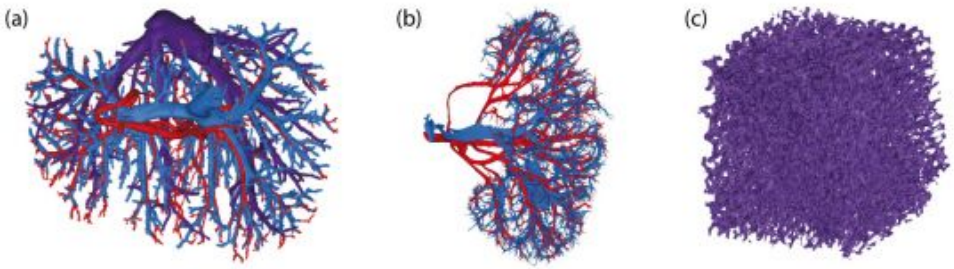

Figure 1. 3D reconstruction of the macrovasculature of a human (a) liver and (b) kidney;
(c) 3D reconstruction of the microvasculature of a sample of sinusoids dissected from a human liver lobule.

References

[1] Debbaut C, Monbaliu D, Segers P (2014) An Engineering Point-of-view on Liver Transplantation Strategies: Multi-Level Modelling of the Hepatic Perfusion. Transplantation Proceedings, 46, 3143-3146.