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Multi-compartment mathematical model for cerebrospinal fluid mechanics coupled to the systemic circulation: Application to transverse sinus stenosis

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Background

The role of vascular abnormalities in the onset and course of neurological diseases has long been recognized. In the last decade, the influence of intra- and extra-cranial venous pathology as a trigger/cause of certain neurological disorders has gained attention. Here we present a model for studying a broad range of such pathologies *in silico*, with the aim of assisting *in vivo* research by providing physical insight into the system under investigation.

Methods

We combine a closed-loop model of the human circulation featuring a detailed description of head and neck veins with a compartment model of the cerebrospinal cavity including brain parenchyma, the four ventricles and their connections, as well as the spinal canal (Figure 1). The model predicted pressure and flow waveforms for blood and CSF are compared against published and patient-specific data. Successively, using a real case study as example for model setup,[1] we investigate the impact of bilateral transverse sinus stenosis on cerebral venous flow and CSF dynamics, as well as the effect of several treatment strategies such as lumbar puncture, unilateral stenting and bilateral stenting, paying special attention to the role played by collateral flow pathways between deep cerebral vessels and extra-cranial regions.

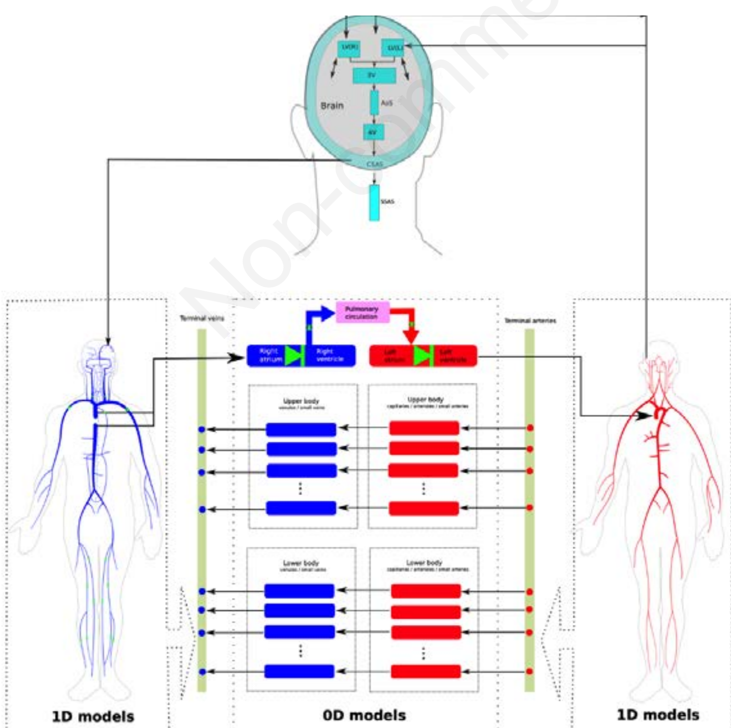

Figure 1. Schematic illustration of the model that couples the following systems: venous and arterial circulation; microcirculation; pulmonary circulation; heart chambers and valves; main CSF compartments and brain parenchyma

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Results

The model is able to reproduce typical blood and CSF pressure and flow waveforms for different districts of the model. Moreover, we reproduce qualitatively and quantitatively results reported in Agarwal *et al.*,[1] up to the extent of a comparison between patient-specific data and our generic model.

Conclusions

We have constructed a model for the detailed study of the interaction of blood flow and cerebrospinal fluids and tissue. The model has been validated for a baseline condition as well as for a pathological case including transverse sinus stenosis and provides a tool for in silico studies of neurovascular pathologies.

References

1. Agarwal, N, Contarino, C, Limbucci, N, et al. Intracranial Fluid Dynamics Changes in Idiopathic Intracranial Hypertension: Pre and Post Therapy. Curr Neurovasc Res 2018;15:164-72.