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The role of collateral vessels in redistributing blood flow during stroke –combining in vivo data with blood flow simulations in semi-realistic networks using an inverse model

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Due to the limited energy storage capabilities of the brain, maintaining a robust oxygen and nutrient supply to all regions of the brain is crucial. During healthy conditions, the interconnected network of blood vessels sustains blood flow to all brain areas. However, during stroke the overall blood supply is reduced drastically. This typically causes tissue damage, which often results in permanent disability or even death.
Generally, the microvasculature of the brain cortex consists of three vessel categories: (1) the surface vessels, (2) the penetrating trees and (3) the capillary bed. Collaterals are blood vessels connecting major feeding arteries at the surface of the brain, e.g. the middle and anterior cerebral arteries (MCA, ACA). If the primary flow path is blocked due to occlusion of the MCA, collaterals provide an alternative route for blood to partially maintain perfusion in the under-supplied brain region (MCA region). Therefore, vascular networks with collaterals are more robust towards tissue damage during stroke [El Amki & Wegener (2017)].
The goal of our work is to better understand the role of collaterals in redistributing flow during stroke and during the subsequent recanalization of the occluded vessel. To date, blood flow can only be quantified in a small number of vessels, hence in vivo measurements only provide limited insight on overall changes in perfusion and on the role of the collaterals. Consequently, we employ numerical simulations [Schmid et al. (2017)] to compute flow and pressure characteristics in large semi-realistic microvascular networks. Here, we present a novel approach to generate such networks by combining realistic arterial networks with an artificial capillary bed. To achieve diameter and flow rate distributions consistent with sparse in vivo measurements, the diameters of the entire network are adjusted by solving an inverse problem using the adjoint method [Epp et al. (2020)]. This allows us to generate large microvascular networks which (a) represent the structure of the real vasculature and (b) are consistent with in vivo measurements in individual subjects with and without collaterals.
Our results confirm that the reduction of overall perfusion after MCA occlusion is less severe in networks with collaterals. Moreover, we show that the redistribution of flow is a direct consequence of the pressure changes initiated by the occlusion and occurs even without collateral dilation. This results in a substantial increase in flow in all collaterals and in the majority of surface arteries at the ACA side, as well as a directed flow from the ACA- towards the MCA-supplied territory.
In summary, our approach allows to incorporate sparse experimental data into blood flow simulations. This strengthens the link between in vivo and in silico studies and allows quantitative and combined study designs. The developed simulation framework enables us to study transient changes during treatment as well as the role of changes at the capillary level during stroke. Both aspects are highly relevant for the recovery of the patient but difficult to study in vivo.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

El Amki, M., & Wegener, S. (2017). Improving cerebral blood flow after arterial recanalization: a novel therapeutic strategy in stroke. International journal of molecular sciences, 18(12), 2669.

Schmid, F., Tsai, P. S., Kleinfeld, D., Jenny, P., & Weber, B. (2017). Depth-dependent flow and pressure characteristics in cortical microvascular networks. PLoS computational biology, 13(2), e1005392.

Epp, R., Schmid, F., Weber, B., & Jenny, P. (2020). Predicting vessel diameter changes to up-regulate biphasic blood flow during activation in realistic microvascular networks. Frontiers in physiology, 11, 1132.

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