Simulating blood flow in the brain’s arterial network enables a better understanding of how disease-related changes in small cerebral arteries (for example in Alzheimer’s disease) affect the blood pressure and flow waveforms in larger arteries, where pressure and flow can be clinically measured.

This thesis focused on the development of a computational model that simulates the cerebral blood flow in detailed subject-specific arterial networks with over 200 branches. The networks are obtained from magnetic resonance images with a specific, limited resolution. To represent those arteries that are too small to be resolved, boundary conditions are required at the truncated network ends.

We developed a method to estimate pressure and flow distributions over the cerebral arterial network ends, for which clinical measurements are not available. In contrast to other methods, we allow multiple possible (stochastic) realizations of boundary conditions, which are constrained by a physiological mechanism that relates flow rate, vessel size, and wall shear stress (Figure 1). Application to differently truncated networks of 50 subjects shows that our method gives improved results over the common approach (Figure 2). It thus contributes to deriving clinical markers to detect and monitor early stages of microvascular changes in conditions such as Alzheimer’s disease.

Figure 1: The new method includes a stochastic variation in the estimation of wall shear stresses.

Figure 2: Application to differently truncated arterial networks of 50 subjects shows that the new stochastic method leads to (a) flow distributions that are independent of the network size and (b) a better agreement between estimated and simulated values.