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An automated multiscale ensemble simulation approach for vascular blood flow

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Abstract
Cerebrovascular diseases such as brain aneurysms are a primary cause of adult disability. The flow dynamics in brain arteries, both during periods of rest and increased activity, are known to be a major factor in the risk of aneurysm formation and rupture. The precise relation is however still an open field of investigation. We present an automated ensemble simulation method for modelling cerebrovascular blood flow under a range of flow regimes. By automatically constructing and performing an ensemble of multiscale simulations, where we unidirectionally couple a 1D solver with a 3D lattice-Boltzmann code, we are able to model the blood flow in a patient artery over a range of flow regimes. We apply the method to a model of a middle cerebral artery, and find that this approach helps us to fine-tune our modelling techniques, and opens up new ways to investigate cerebrovascular flow properties.

Keywords: multiscale modelling, blood flow, ensemble simulation, parallel programming, high-performance computing

1 Introduction

Stroke is a major cause of death and morbidity in the developed world. Subarachnoid haemorrhage (SAH) is a type of stroke characterised by bleeding into the fluid around the brain, for example due to the rupture of an intracranial aneurysm. An aneurysm is a congenital weakness in a blood vessel wall which gradually bulges out to form a balloon which can eventually burst. SAHs represent 5% of cases of stroke, but is relatively more important, as the mortality rate