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Comparison of lattice Boltzmann method and finite volume method for the study of blood flow in cerebral aneurysms

Jon McCullough[*†], Ivan Benemerito[*§#‡], Alberto Marzo[§‡], Andrew Narracott[#‡], Peter Coveney[†+]

The concept of digital twins for healthcare promotes the use of personalised simulation models to help guide the treatment decisions of clinicians for a particular patient. Given the maturity of computational fluid dynamics as a field, one area of clinical practice where particular effort has been focussed for digital twins has been in cardiovascular diseases where the complex flow patterns are particularly amenable to numerical study. The goal of such work is to provide clinicians with insight into the risk profile of a patient given their condition and to help provide insight into the efficacy of potential treatment options.

In this study, we have focussed our attention to flows within cerebral aneurysms. We have chosen to investigate an aneurysm of the middle cerebral artery (MCA) and internal carotid artery (ICA) as these represent a significant proportion of the cases observed by clinicians. In particular, we wish to evaluate the performance of two different numerical approaches for solving flows in these domains. The first is the well-known commercial solver Ansys CFX that directly solves the Navier-Stokes equations for fluid flow within a domain using a finite volume strategy. The second is the open-source solver HemeLB that utilises the lattice Boltzmann method to solve fluid flows. Each approach has benefits and drawbacks in computational performance and overall usability for both expert and non-expert users. Common boundary conditions are applied to the respective approaches with these being generated from a population of vascular geometries. The profiles generated as an average of this population are used in both solvers to examine specific flow profiles within the aneurysm at the systolic peak and over the duration of the heartbeat cycle. Simulations were also run with the entire population of profiles to examine how key clinical metrics in assessing the risk of aneurysm rupture vary between the two solvers (Figure 1).

These studies have shown particularly good agreement between the two solvers for the MCA case. In this presentation, we will discuss the comparison of results between the two approaches and how this may potentially impact the choice of solver used within a digital twin setting.

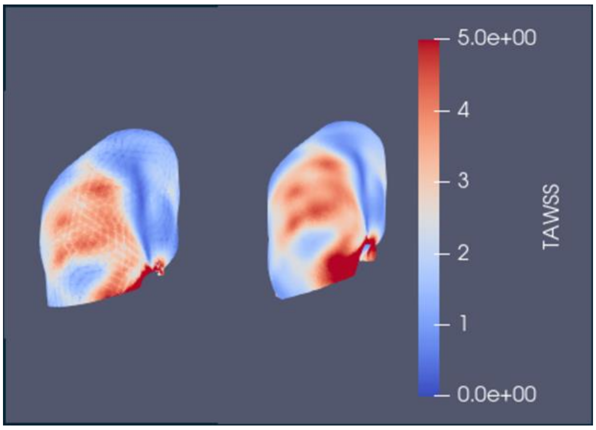

Figure 1: Distribution of time-averaged wall shear stress over the MCA aneurysm dome for HemeLB (left) and CFX (right), with colour bar values capped at 5 Pa.

[*] School of Mechanical and Aerospace Engineering, Queen’s University Belfast, United Kingdom
[†] Department of Chemistry, University College London, United Kingdom
[§] School of Mechanical, Aerospace and Civil Engineering, University of Sheffield, United Kingdom
[#] School of Medicine and Population Health, University of Sheffield, United Kingdom
[+] Informatics Institute, University of Amsterdam, Netherlands
[‡] INSIGNEO Institute for In-silico Medicine, University of Sheffield, United Kingdom