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ON NUMERICAL METHODS FOR TRANSITIONAL FLOW – APPLICATION TO BLOOD FLOW IN CEREBRAL ANEURYSMS

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Computational fluid dynamics (CFD) have demonstrated its potential for stroke prediction, e.g. by providing better risk estimators for aneurysm rupture than traditional discriminants based on aneurysm morphology [1, 2] and it is likely that CFD will be used in clinics in the near future. A recent benchmark [3] has, however, shown that performing blood flow simulations in cerebral aneurysms is challenging because the simulation results varied considerably among the different participants in the benchmark even though surface geometry and boundary conditions were given.

Recent studies have demonstrated that the blood flow in aneurysms may sometimes be transitional or even turbulent in parts of the cardiac cycle [5, 6]. The fact that transitional flow may be precent, even at moderate Reynolds numbers significantly below 1000 is not new. Already in 1970 Ferguson [4] demonstrated turbulence both *in vivo* and *in vitro*. Still, most numerical simulations within this area assume laminar flow and choose schemes and resolution accordingly.

As pointed out in [3], at least part of the explanation for the variability in simulation results are due to different resolutions. This was further explored in a recent paper [7] that demonstrated that high resolution simulation revealed significantly more complex flow as compared with more commenly used resolutions.

A wide range of different schemes have been used for CFD simulations of aneurysmal blood flow. While numerical schemes targeting transitional flow employ high resolution and schemes that introduce little dissipation, laminar flow simulations typically employ stabilized schemes with dissipation to ensure convergence at coarser resolution. Obviously, as also pointed out in [7], high resolution is required to capture the small structures involved in transition. Whether it is neccessary to choose special schemes that target transition or that standard schemes can be used at a reasonable resolution is an open question. In this talk we discuss transitional flow simulations performed with different

schemes at a reasonable resolution. In particular, we will investigate whether special time integrators are neccessary for capturing transition. The simulations are performed using FEniCS [8].

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