Aneurysms involve a local dilatation or ballooning of a blood vessel and can have fatal effects, such as severe bleeding, when they rupture. The thinning of the aorta walls, together with the increase of wall shear stresses beyond the strength of the blood vessel tissue, lead to the rupture of the same. In order to avoid the aneurysm rupture, stent grafts are held in place through endovascular repair. However, these grafts are subjected to drag forces which are further transferred to the very blood vessel. The success of these implants depends upon how long they can be held in place without getting significantly displaced. In order to gain knowledge on this aspect, in the present study we perform CFD simulations of blood flow in a patient-specific thoracic aortic aneurysm (TAA) without and with a stent graft and an idealized abdominal aortic aneurysm (AAA).

The bulk of the simulations in this study will be performed using OpenFOAM [1] which is an open source CFD solver. OpenFOAM solves the incompressible Navier-Stokes equations using a finite volume method with second-order accurate discretization schemes. The turbulence model chosen is large eddy simulation (LES) motivated by the desire to capture unsteady vortical structures previously observed in AAA simulations of Biasetti et al. [2]. To address the issue of the use of low-order numerics in OpenFOAM, we also plan to carry out LES using an in-house high-order solver named WenoHemo™ [3]. WenoHemo™ is based on high-order finite difference methods on a Cartesian grid with the immersed boundary method to handle complex geometry.

The schematic of the TAA and the AAA geometries under consideration are shown in Figures 1 and 3 respectively. The vessels are assumed to be rigid and blood is modeled as Newtonian with a constant density and viscosity of 1050 kg/m³ and 0.0035 Pa.s, respectively. Various boundaries are shown marked in TAA in Figure 1. Inlet boundaries employed a known velocity profile with homogeneous Neumann condition for the pressure, and the outlet boundaries have a Dirichlet condition on pressure. A steady velocity profile is specified at the inlet as a first approximation; however in reality the inlet velocity profile is pulsating. The inlet velocity was taken as 0.059 m/s from Morris et al. [4]. This makes the flow laminar with Re = 584. In Figure 2, we show contours of velocity magnitude on the central plane, simulated using steady state laminar flow solver of OpenFOAM [1]. A prominent re-circulating region can be seen in the aneurysm which contains two counter rotating vortices about the anterior-posterior axis. Next in order to validate our solver, we
performed simulations on the AAA geometry with Re = 500 using WenoHemo™. Figure 4 presents a comparison of axial velocity profiles at different locations along the aneurysm and a good agreement with the experimental results of Asbury et al. [5] is achieved.

Further in the present study, we will perform simulations with pulsating inlet velocity profile. Also, simulations with stent grafts (geometry not shown here) will be performed in order to compute the forces acting on them. We will study the changes in the flow structure, mean and peak wall shear stresses on the aorta walls with the introduction of the stent graft.

References: