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CFD CHALLENGE: SOLUTIONS USING THE COMMERCIAL FINITE VOLUME SOLVER FLUENT ON TETRAHEDRAL AND POLYHEDRAL MESHES

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Introduction

Research by the Malek Computational Hemodynamics Laboratory has focused on using computational fluid dynamic (CFD) tools to gain an improved insight of the mechanical environment faced by endothelial cells in and around cerebrovascular atherosclerotic and aneurysmal lesions. More recently, we have been interested in studying the effect of endovascular therapies such as aneurysm-occluding coils and intravascular stents on local microhemodynamics.

Methods

Meshing was performed using three different methods: 1) by using the commercial meshing capability of Star-CCM (CD-Adapco) to obtain a polyhedral mesh (988,000 faces / 128,000 polyhedral elements) with prismatic enhancement on the wall, 2) by using the commercial mesher Harpoon (Sharc) to generate a tetrahedral mesh (3,400,000 faces / 1,640,000 tetrahedral elements) with boundary layer enhancement on the wall using 3 layers at a 1.2 expansion ratio and local refinement based on Gaussian curvature and proximity, 3) by using the mesh generated in 2) and performing a polyhedral domain conversion using Fluent (Ansys) to obtain a final polyhedral mesh containing (2,200,000 faces / 351,000 polyhedral elements).

Solver used was the finite volume solver Fluent v.13 in all cases running in double precision mode on a quad-core Intel Core i7 or dual quad-core Intel Xeon workstation in the Microsoft Windows 64 environment. Solver was pressure-based using Simple pressure-velocity coupling with using node-based (for tetrahedral) and cell-based (for polyhedral) standard pressure and second-order upwind spatial discretization. Transient analysis was by fixed-time stepping was used with 200 uniform steps of 0.005 second. Convergence criteria was for residual reaching below 10e-3 for continuity and all three components.

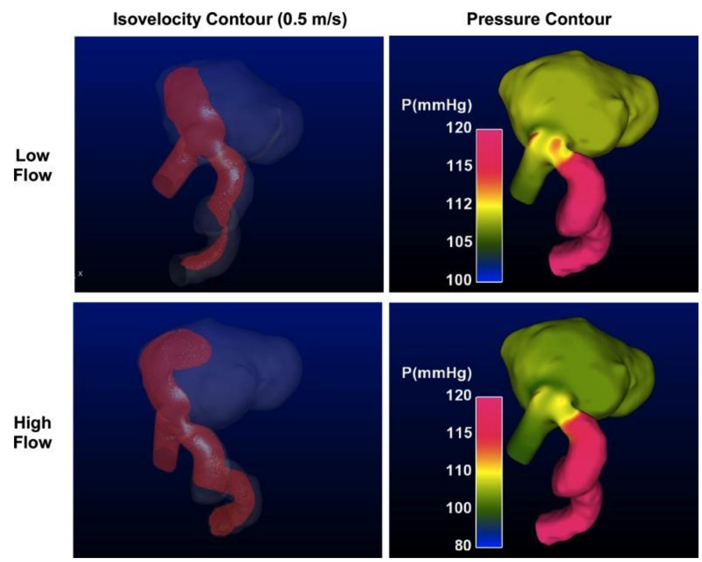

Figure 1: Isovelocity contour (left column; v=50 cm/sec) and Pressure contour (right column) for low flow (Q=9.14 mL/sec, top) and high flow (Q=11.42 mL/sec) using the polyhedral mesh

Results

Evaluation of the flow pattern within the dome showed a subtle but definite dependence of the flow pattern on the mesh density with a main vortex near the inflow zone of the aneurysm which led to a second less prominent but incomplete vorticial pattern near the more distal prominence of the dome. As expected, the higher density polyhedral mesh resulted in improved spatial resolution. Both polyhedral meshes converged significantly faster and more completely when compared to the tetrahedral mesh resulting in significant shortened computational time on the order of 2-4 fold.

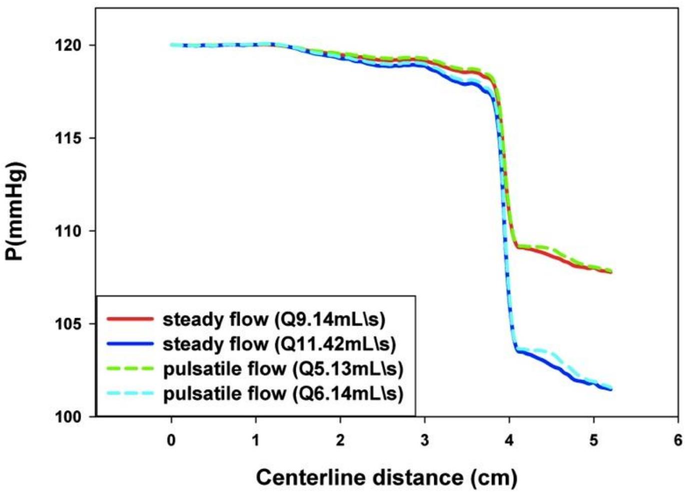

Figure 2: Centerline pressures at peak systole for the pulsatile cases at (Q = 9.14 and 11.42 mL/sec). Results from high-density polyhedral mesh.

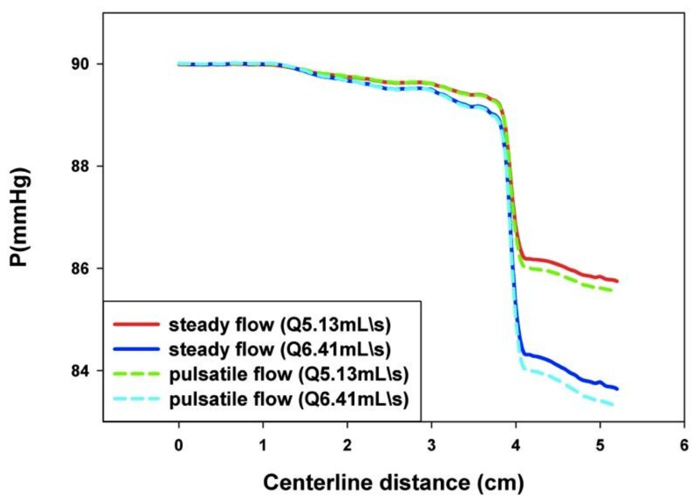

Figure 3: Cycle-averaged centerline pressures along with pressures from the two corresponding steady flow cases (Q = 5.13 and 6.41 mL/sec). Results from high-density polyhedral mesh.

Discussion

Analysis using three different types of mesh configurations led to very similar centerline pressures with near identical profiles. In contrast, there was greater variability within the aneurysm dome with respect to the flow patterns and accordingly, the resulting wall shear stress, depending on the type of mesh and density used. This is an important dependence which needs further exploration when determining an approch to evaluate wall shear stress pattern and aneurysm pathophysiology.

Acknowledgments:

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References:

[1] Baharoglu, M.I., Schirmer, C.M., Hoit, D.A., Gao, B.L, and Malek, A.M., 2010, “Aneurysm Inflow-Angle As A Discriminant For Rupture In Sidewall Cerebral Aneurysms: Morphometric and Computational Fluid Dynamic Analysis,” Stroke, 41, pp. 1423-1430.

[2] Schirmer, C.M., and Malek, A.M, 2010, “Critical Influence Of Framing Coil Orientation On Intra-Aneurysmal And Neck Region Hemodynamics,” Neurosurgery, 67(6), pp 1692-1702.