VMTK - Fluent – RBF Morph: A New Workflow For Hemodynamics Applications

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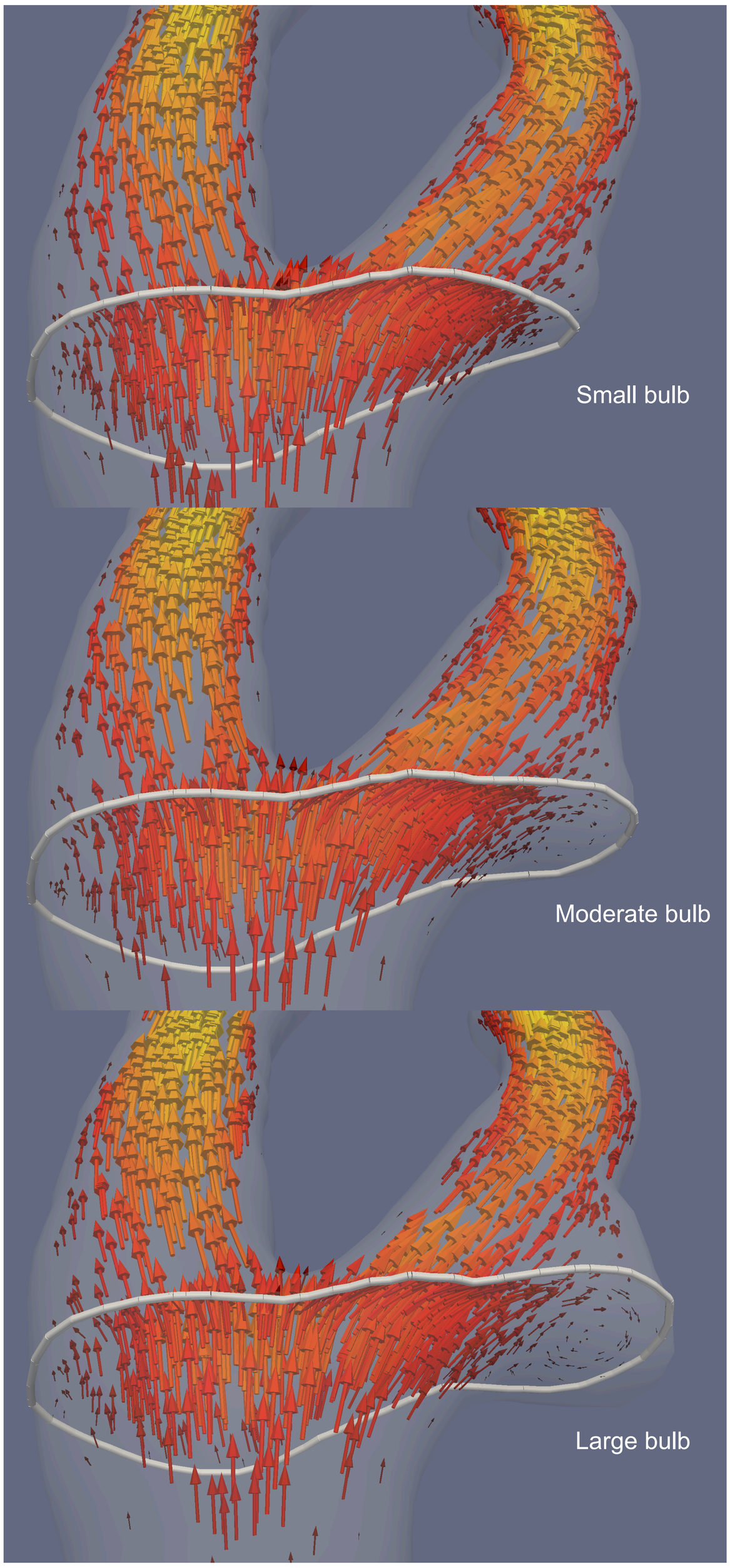
Introduction. Engineering applications involving biological fluids have highly transversal requirements in terms of domain definition from clinical images, complex flow conditions, fluid rheological properties, structure motion and deformation, visualization and post-processing of the results.

In this work we present a new workflow based on three fully validated software used to effectively fulfill the requirements related to hemodynamics:

- the Vascular Modeling Toolkit (**VMTK**) for the pre-processing step;
- the mesh morphing tool **RBF Morph** to impose changes to the vascular anatomy;
- **Ansys Fluent** as Navier-Stokes CFD solver.

As a first test case we focused our attention on the study of a subject-specific carotid bifurcation being this anatomical site of major interest in hemodynamics and its relation to atherosclerosis. The present study is focused on the effect of the shape of the carotid bulb on the resulting flow patterns, which are thought to be tightly related to the focal development of atheromatous plaques at that site.



The Vascular Modeling Toolkit is a collection of open-source libraries and tools for 3D reconstruction, geometric analysis, mesh generation and surface data analysis for image-based modeling of blood vessels. It has been designed to provide seamless integration with downstream CFD software, with particular attention to Ansys Fluent.For the present application, it has been used to segment the carotid bifurcations from clinical magnetic resonance (MR) images, to and characterize the obtained anatomy (centerlines, radius, bifurcation geometry, branch geometry, section areas, curvature, tortuosity), to generate a suitable mesh for CFD and export it directly to Fluent msh format.

RBF Morph is a unique morpher that combines a very accurate control of the geometrical parameters with an extremely fast mesh deformation, fully integrated in the CFD solving process. RBF Morph is the meeting point between state-of-the-art scientific research and top-level industrial needs. For the present application it has been used to impose clinically relevant modifications on the carotid bifurcation geometry such as changes on relative internal/external angle (ICA/ECA angle), deformation of the carotid bulb (shown on the left) and presence of a stenosis on the ICA branch.

Ansys Fluent is a comprehensive commercial product suite for modeling fluid flow and other related physical phenomena. It's one of the most widely used software for many engineering applications. Here we used the 3D double precision unsteady segregated pressure-based solver studying Newtonian and non-Newtonian flow behavior and extracting qualitative and quantitative hemodynamics parameters (wall-related indices such as OSI and TAWSS) via user-defined functions (UDF).

Conclusions

Thanks to the new workflow, a comprehensive fluid dynamics study of a patient-specific carotid bifurcation with several clinically relevant anatomical modifications has been successfully performed. The power, the usability and the full level of integration demonstrated by the three computational bricks, together with the possibility of exploiting their features in High Performance Computing environments make this new workflow very attractive for future applications on a wide range of clinically relevant hemodynamics problems. The parametric nature of the model allows an easy integration of the workflow with additional computational tools (modeFRONTIER, Ansys DesignXplorer) for shape optimization problems and medical device design.