Simulation of the Three-Dimensional Blood Flow in Stenosed Coronary Arteries: Semi-Automatic Generation of the Mesh

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In current clinical practice, physicians make extensive use of medical images for diagnosing and planning therapy, but they frequently confine themselves to a visual inspection of the morphology.

The diagnosis of cardiovascular diseases and the planning of therapy should be based on a fair knowledge of the patient's hemodynamic state. This is particularly true of coronary artery disease in cases where severe stenoses in the coronary arteries increase resistance to flow. Stenoses may reduce the flow of blood to such an extent that the myocardium becomes vulnerable to ischemia. The disturbed flow around stenoses accelerates the progression of the atherosclerotic changes and may cause the formation and development of thrombi. Thus, patient-specific simulation studies of the blood flow are required which must be based on the patient's medical images (biplane angiograms).

We aim at the development of a simulation system which would allow physicians to assess their patient's hemodynamic states. This paper focuses on the semi-automatic generation of a mesh that is required for the three-dimensional simulation of the blood flow through the coronary arteries with pathological changes (stenoses) based on biplane angiograms. The simulation studies are then carried then by employing a commercial CFD software system (FIDAP).

The generated mesh fully considers the patient-specific geometry. Generating the mesh involves the acquisition of the geometry (three-dimensional reconstruction based on biplane angiograms), the creation of a meshable geometric model, and the implementation of the mesh. We aim at the generation of an optimal mesh that would allow us to compute the solution with a specified accuracy at minimal cost in terms of computing time. To do this, we must adapt the size of the elements to the flow conditions. As a consequent adaptive procedure with an a posteriori error analysis would consume too much time, we decided to employ a priori criteria for the adaptation. Although these criteria are in principle heuristic in nature, they nevertheless reflect a fair quantitative a priori knowledge relevant to the coronary artery under investigation. This quantitative knowledge is derived from a posteriori analyses of computed flow conditions in so-called reference flow domains.

In this paper, we will give an overview of the acquisition of the geometry of the flow domain, describe our mesh generation approach, and present simulation results.