

DISSERTATION
DEFENSE

*Numerical Modeling of Blood Flow Problems in Coronary
Arteries: Patient-specific Processing, from Stented Geometries
to Fluid Dynamics*

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Abstract: Coronary stents expand the vessel to alleviate blockage, and they have been used for decades to save lives from coronary heart disease. Technological development has driven the evolution of stenting from bare or drug-coated metallic stents to the newly invented bioresorbable vascular stent (BVS). Rather than leaving a permanent metallic structure in the vessel, a BVS can dissolve in the body after opening the blocked artery, restoring the diseased coronary artery to its natural state. The BVS compensates for its decreased radial strength by having thicker struts that could cause disturbed blood flow, resulting in delayed healing and other devastating complications. Computational fluid dynamics (CFD) simulations had been used to analyze the potential risk of the BVS, but those simulations were conducted on either arbitrary geometry or partially patient-specific geometry with overly smoothed or virtually deployed stents. In this thesis, we present a novel methodology to reconstruct true patient-specific CFD simulations: the geometry of a deployed stent inside a living patient is reconstructed from optical coherence tomography (OCT) images; the shape and the curvature of the stented vessel are obtained from angiography; and a real pulsatile flow rate profile can also be prescribed as inflow condition, when it is available. With patient-specific geometry, the CFD results reflect the true hemodynamics after stent deployment and describe the wall shear stress (WSS) and other quantities. We also aim to make the reconstruction and simulation process automatic, so that a large number of patients can be processed in a short time in order to draw statistically convincing conclusions. In fact, the entire process of the computational patient-specific analysis is expected to become a routine in clinical trials and activities (Computer Aided Clinical Trials, CACT). This has created significant challenges in the methodological approach, ranging from image analysis, image processing, computational geometry and eventually fluid dynamics. These work witnesses the different challenges of this multi-component procedure. We hope the patient-specific reconstruction and simulations study can further the understanding of the BVS, improve its design, and ultimately expedite the tedious validation process so that it can soon become a soldier for us in the battle against coronary heart disease.

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