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BLOOD FLOW MODELING IN A BEATING HUMAN HEART

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Cardiovascular disease is the leading cause of death[1] in developed countries and extracts a high socioeconomic cost. Implanted medical devices hold great promise in improving heart function; however, cardiac motion can affect device stability and performance while the presence of the device can alter the motion in return. Over the long term, effects as well as modified blood flow patterns may lead to structural remodeling that can have adverse on cardiovascular function. Computational tools are uniquely capable of accounting for cardiac/vascular tissue mechanics, blood flow, and the interaction between them, yet are currently under-utilized due to their complexity. The Living Heart Model (LHM), an anatomically and physiologically realistic 3D model of a human heart, provides a framework to systematically analyze, visualize, and optimize device-heart interaction[2]. In this paper, we focus on the LHM for 3D blood flow modeling to better understand the human heart in both healthy and diseased states as well as to improve the efficacy of cardiovascular medical devices and to guide the clinical treatment of heart disease.

Applications of blood flow modeling today encompass a wide variety of conceptual and technical approaches, ranging from 1D lumped parameter models (LPMs) of the cardiovascular system to highly detailed 3D fluid-structure interaction (FSI) simulations. We begin by discussing how low-fidelity LPMs have been used to introduce disease-specific characteristics in the LHM following which detailed 3D device-heart simulations can be conducted. Next, we discuss the use of various 3D flow modeling techniques to assess the efficacy of medical devices, particularly in the context of valvular diseases where small hemodynamic changes can have large consequences. We conclude with two applications of blood flow modeling in clinical scenarios. In the first application, we explore the likelihood of rupture of abdominal aortic and carotid aneurysms. In the second application, we examine the surgical treatment of Hypoplastic Left Heart Syndrome (HLHS). These examples demonstrate the value of simulation for patient-specific real-world clinical workflows.

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