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Numerical Modeling of Cardiovascular Flows: Integrating High Resolution CFD and Experimental Techniques

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In recent years the advent of powerful and affordable computational platforms along with the development and proliferation of advanced commercial and academic software have contributed to the emergence of CFD as a useful bioengineering research tool alongside with in vitro and in vivo studies. Cardiovascular flows take place in complex, multi-connected domains with compliant walls and flexible immersed boundaries and are dominated, among others, by pulsatile effects, 3D separation and vortex formation, regions of flow reversal, periodic transition to turbulence and laminarization, and non-Newtonian effects. These complexities pose unique modeling challenges and necessitate a close synergy and integration between CFD modelers and experimentalists to guide model development and validation. In this paper we report recent progress toward the development and validation of a high resolution numerical method capable of quantitatively accurate predictions of complex cardiovascular flows. The method employs domain decomposition with body-fitted, domain-structured, Chimera overset grids to discretize arbitrarily complex, multi-connected geometries. Results will be presented for two flow cases, each representative of different kinds of modeling challenges: 1) flow through a bileaflet mechanical heart valve with the leaflets fixed at the fully open position; and 2) flow through an anatomically realistic Total Cavopulmonary Connection (TCPC). For both cases the numerical simulations and laboratory experiments are carried out concurrently to validate the numerical model and elucidate the complex hemodynamics of these flows over a range of Reynolds numbers.

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