Isogeometric Analysis of blood flows in the heart: a numerical study in idealized and patient–specific left ventricles

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ABSTRACT

We consider the numerical study of the blood flow dynamics in three–dimensional left ventricles of the human heart, both in idealized and patient–specific configurations, whose deformation along the heartbeat is driven by muscle contraction and relaxation in coordination with the action of the mitral and aortic valves [3].

Our computational pipeline starts with the geometrical representation of the fluid domain by means of NURBS; in the patient–specific case, we build the left ventricle geometry and we reconstruct its deformation by fitting the available medical images of the patient along the heartbeat. For the spatial approximation of the incompressible Navier–Stokes equations in Arbitrary Lagrangian–Eulerian formulation, we use NURBS–based Isogeometric Analysis in order to exploit both the "exactness" of the domain representation and the accuracy properties of globally high order continuous NURBS basis functions [2]. In addition, we model turbulence according to LES principles by means of the Variational Multiscale Method [1] and we consider a simplified but realistic treatment of the valves function as mixed time–varying boundary conditions, which, at the numerical level, are enforced by means of the extended Nitsche's method [4].

We show the complex intraventricular blood flow patterns and we critically discuss the numerical results, both in terms of instantaneous and phase–averaged quantities of interest. In particular, we highlight the transitional nature of the flow and and its main features along the heartbeat.

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