Abstract:
The simultaneous replacement of a diseased aortic valve, aortic root and ascending aorta with a composite graft equipped with a prosthetic valve is a nowadays standard surgical approach, known as the Bentall procedure: the Valsalva sinuses of the aortic root are sacrificed and the coronary arteries are reconnected directly to the graft. In practice, two different composite–material prostheses are largely used by surgeons: a standard straight graft and the Valsalva graft with a bulged portion that better reproduces the aortic root anatomy. An accurate three-dimensional numerical method, based on the immersed boundary technique, is proposed to study the flow inside moving and deformable geometries, with the aim of studying the effect of the graft geometry on the the flowfield as well as on the stress concentration at the level of coronary–root anastomoses during the cardiac cycle. Direct numerical simulations of the flow inside the two prostheses, equipped with a bileaflet mechanical valve with curved leaflets, under physiological pulsatile inflow conditions are presented. The dynamics of the leaflets (considered rigid) is obtained by a fully-coupled fluid-structure-interaction approach, while a weak-coupled approach is employed for the deforming roots, in order to reduce the computational cost, using optimized solvers for both the fluid and the structural problems. The Dacron material is modeled as orthotropic, with an inversion of the material properties in the longitudinal and the circumferential direction for the skirt region of the Valsalva prosthesis. Coronary perfusion is reproduced modulating in time the porosity, and thus the resistance, of the coronary channels. The results show that, while the pseudo-sinuses do not significantly influence the coronary entry-flow, using the Valsalva graft the stress level near the coronary–root anastomoses is about half that obtained using the standard straight graft, potentially reducing post-operative complications.

Short Bio:
Marco D. de Tullio graduated cum laude in Mechanical Engineering at the Politecnico di Bari in 2003. He obtained a PhD in Mechanical Engineering at the Politecnico di Bari in 2007. During the PhD period, he spent several months at the Center for Turbulence Research of the Stanford University, working on the development of an immersed boundary method for compressible flows. He is now a postdoc researcher at Politecnico di Bari, where he teaches courses of Fundamental Fluid Dynamics and Turbulence. His research is focused on the development and improvement of the immersed boundary technique for compressible flows, with particular emphasis on wall modeling, as well as the application of the immersed boundary technique for incompressible flows to moving and deforming geometries, oriented to biomedical applications.

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