Personalized computational hemodynamics framework to assess the long-term performance of Transcatheter Aortic Valve Implantation

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Abstract:
Transcatheter Aortic Valve Implantation (TAVI) was introduced for treating aortic stenosis in elderly patients at surgical risk and is currently becoming the first-choice therapy even in low-surgical-risk younger patients [1]. In this context, it is particularly relevant to assess the long-term performance of the bioprosthetic valves used for TAVI. This computational retrospective study aims to investigate the relationship between early post-TAVI aortic hemodynamics and Structural Valve Deterioration (SVD), which is the main limiting factor to the durability of TAVI valves. We build on previous findings [2] to propose computational risk scores able to identify a premature onset of SVD.
The study population comprises patients with and without SVD at long-term follow-up exam. We reconstruct pre-operative patient-specific geometries and we create post-TAVI scenarios by virtually inserting a valve model representing the particular bioprosthetic valve implanted in that patient. Computational Fluid Dynamics (CFD) simulations are performed in such virtual scenarios imposing an inflow condition, personalized by considering patient-specific cardiac outputs and velocity temporal evolutions. The numerical results are then post-processed with the aim of discriminating between the SVD and non-SVD groups.
The CFD results showed that the TAVI valve highly influences aortic hemodynamics, characterized by a high velocity jet in the ascending aorta and vortical structures around this jet. Depending on the patient-specific geometry and blood flow features, the evolution of the jet and vortices generates shear stress patterns on the aortic wall and bioprosthetic leaflets that are used to formulate the risk scores.
The results of this study suggest that post-TAVI blood dynamics may have an influence on the development of SVD. Moreover, the proposed risk scores could potentially assist clinicians in a patient-specific planning of follow-up exams, moving toward a personalized care.
[1] Cesario et al; J Clin Med; 13(20):6123; 2024.
[2] Crugnola et al; CMPB; 259:108517; 2025