COMPUTATIONAL PREDICTION OF THE DEGENERATION OF TRANSCATHETER AORTIC VALVE IMPLANTATION

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Introduction

Transcatheter Aortic Valve Implantation (TAVI) is a minimally invasive technique for the treatment of severe aortic stenosis (AS). Since the first procedure in 2002, TAVI has revolutionized the management of AS and become the standard of care for patients with AS at prohibitive surgical risk, and the preferred treatment for many intermediate and high-risk elderly patients [1]. Moreover, the results of recent clinical trials suggest that TAVI might be the preferred option for AS treatment even in low-risk, younger patients [2]. However, Structural Valve Deterioration (SVD), an irreversible degenerative process typical of bio-prosthetic leaflets tissue, can drastically reduce the long-term durability of the implanted valve [3]. The exact mechanisms underlying SVD are not completely understood, thus there is an increasing interest in studying this phenomenon.

Computational Fluid Dynamics (CFD) models have been mostly employed in the TAVI framework to study paravalvular leakage [4], whereas, to the best of our knowledge, only few authors tried to study SVD using a CFD approach [5].

The aim of this study is to employ a CFD model to numerically simulate post-TAVI hemodynamics inside patient-specific aortic roots and ascending aortas starting from pre-operative images, in order to identify correlations with SVD.

Methods

The available clinical data, thanks to our collaboration with Monzino Cardiology Center, Milan, is a dataset of pre-TAVI Computed Tomography (CT) scans, balanced between patients who have experienced a premature onset of SVD after TAVI (degenerated cases) and patients who did not (non-degenerated cases). Starting from such CT scans the patient-specific aortic geometries, together with calcifications, have been reconstructed in order to generate post-TAVI computational domains by virtually implanting the valve in those geometries. In particular, in this study we considered the Edwards Sapien TAVI valves. CFD simulations are then carried out inside the generated computational domains and the results are post-processed in order to identify quantities that allows us to differentiate between the two subsets of patients.

Results

CFD results showed that the presence of the TAVI valve gives rise to a high velocity jet in the ascending aorta and to the generation of vortical structures around this jet, as shown in Figure 1. Such structures collide with the aortic wall generating great shear stresses on the endothelium and a highly disturbed flow inside the aorta. We found that patients with degenerated TAVI present higher shear stresses and flow disturbances with respect to the non-degenerated ones, providing a clear separation between the two groups.

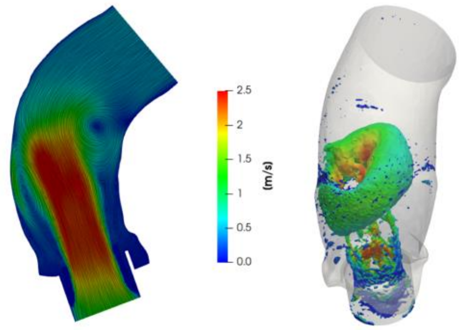

Figure 1: Left: Velocity streamlines on a longitudinal section; Right: Vortical structures, colored by velocity, quantifying flow disturbances.

Discussion

These results suggest a correlation between a premature onset of SVD and great shear stresses and flow disturbances in the ascending aorta. High shear stresses on the aortic wall can damage both the endothelial and the blood cells, whereas the highly disturbed flow generated by the collision of the vortical structures on the aortic wall allows particles to remain inside the aortic root during the whole cardiac cycle. Thus, we think that blood-dynamics inside the ascending aorta could in principle have an impact on SVD.

This is an ongoing project, indeed we aim at employing the presented CFD approach to a wider population in order to support our findings.

References

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