PRE-OPERATIVE RISK ASSESSMENT OF PARAVALVULAR LEAKAGE USING A COMPUTATIONAL TAVI DEPLOYMENT MODEL

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Introduction

The aortic valve is prone to dysfunction as it has to withstand a high-pressure gradient during diastole [1]. One of the most common aortic valve diseases is aortic valve stenosis, which is defined by the narrowing of the valve opening area caused by stiffening of the leaflets due to calcifications that restrict the valve movement. For high-risk patients, the disease is treated by Transcatheter Aortic Valve Implantation (TAVI), a minimal invasive technique in which an expandable prosthetic valve is inserted into the aortic root via cardiac catheterization. TAVI is still associated with a high risk of complications such as paravalvular leakage (PVL), where blood can flow back into the left ventricle [2]. In this contribution a computational framework to model the TAVI procedure is introduced which can be used to perform a fast, qualitative pre-operative risk assessment of paravalvular leakage.

Numerical method

An explicit finite element model is developed to simulate the TAVI procedure in patient specific, or synthetic, aortic root geometries. To verify the model, convergence tests on a periodic part of the initial device geometry, representing one loop of a CoreValve TAVI stent, are performed. To study the effect of the degree of calcification on the risk of paravalvular leakage, devices of different sizes are simulated for mildly and severely calcified valve leaflets. Finally, a postprocessing tool is developed to perform a pre-operative risk assessment of paravalvular leakage, using the deployed shape of the device and the patient specific aortic root anatomy. To this end, the Reynolds equation for a pressure driven, stationary, incompressible, viscous Poiseuille flow [3] is solved on the fluid volume between the aortic vessel and the device in the vicinity of the aortic annulus.

Results

Results show that the presence of calcifications on the valve leaflets lead to an increased risk for paravalvular leakage. Figure 1 shows the simulation result of a medium sized device deployed in a highly calcified synthetic aortic geometry of an average female. To estimate the leakage, the fluid flux is calculated and is indicated by the arrows. An estimation of the regurgitant flow rate of blood flowing past the device back into the left ventricle can be obtained using this method. Furthermore, the method allows for fast qualitative patient-specific profiling of PVL.

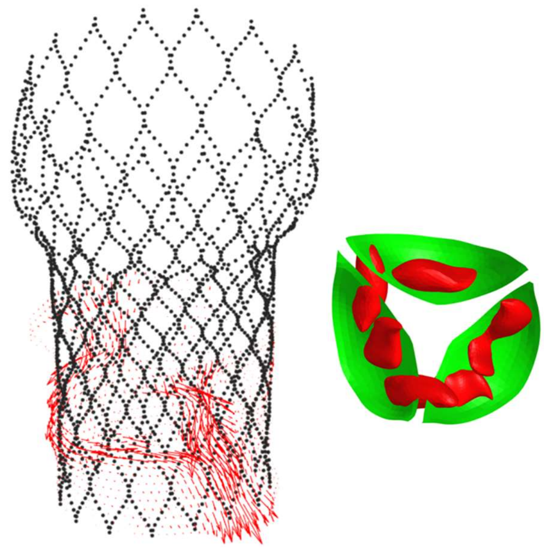

Figure 1: Left: Leakage estimation for a medium sized device deployed in a synthetic average female aortic geometry for highly calcified valve leaflets. Right: The valve leaflets (green) and the calcification nodules (red).

Discussion and conclusion

The developed computational model can be used to perform a pre-operative risk assessment of paravalvular leakage in patient specific aortic root anatomies. The method presented here allows for fast, qualitative patient-specific profiling of PVL for different aortic pressures. A first validation shows that the regurgitant flow rate is larger for a more severe degree of stenosis. Validation of the computational deployment framework will be performed by comparing numerical results of the deployed shape of the TAVI device to patient specific data.

References

1. F. Auricchio, M. Conti, S. Morganti and A. Reali *Computer Methods in Biomechanics and Biomedical Engineering,* 17:1347-1357, 2014
2. C. Russ, R. Hopf, S. Hirsch, S. Sundermann, V. Falk, G. Szekely and M. Gessat *35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* 35:711-714, 2013.
3. A. G. Shvarts, V.A. Yastrebov *Tribology International,* 126:116-126, 2018

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