THE EFFECT OF PRE-STRESS IN TAVI PROCEDURE FINITE ELEMENT SIMULATIONS ON PATIENT SPECIFIC GEOMETRIES

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Introduction

In silico modelling of cardiovascular surgical procedures is an important tool used to assess and further analyse their outcome. A number of methods have been proposed to account for the stress state of vessels, which comes from internal blood pressure, reconstructed from diagnostic images. Not considering this pre-stress may result in inaccuracies when studying the interaction of the vessel with implantable devices [1,2]. However, it is important to demonstrate that its application leads to more reliable results. This can be achieved by highlighting the differences in the results between simulations in which the unloaded configuration is taken into account and simulations in which it isn't, and comparing the results with real cases. This work studies the effect of the unloaded configuration on finite element simulations of Transcatheter Aortic Valve Implantation (TAVI) on patient specific geometries [3].

Methods

Patient specific geometries reconstructed from CT images in [3] were used. The unloaded configuration was obtained by means of inverse elastostatic (IE) methods [4] extended to work with anisotropic materials. The idea behind these algorithms is to predict the real stress-free configuration of the vessel, which is the shape it would assume if no blood pressure was applied on the internal wall, and is called zero-pressure configuration. The unloaded vessel is then pressurized up to diastolic condition obtaining a geometry deformed as in the original diagnostic image but with stressed walls (Figure 1). Results of simulations considering and not the unloaded configuration were compared in terms of possible complication detection, device positioning and vascular damage.

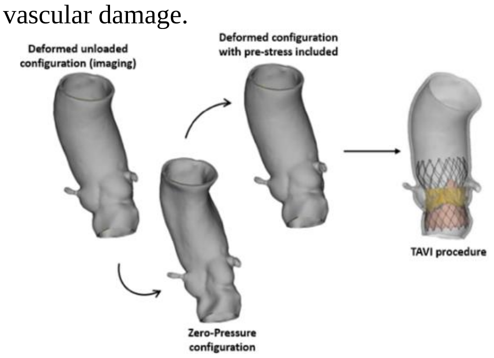

Figure 1: Workflow applied to implement simulations

Results

The comparison of the simulations shows some important differences with results more similar to the in-vivo conditions when the unloaded configuration is accounted for. Accounting for the unloaded geometry modifies the deployment of the valve providing a better anchoring in the anulus region, but worsen the anchoring in distal positions. In addition, the stresses in the aortic wall result larger when the zero-pressure configuration is considered (Figure 2).

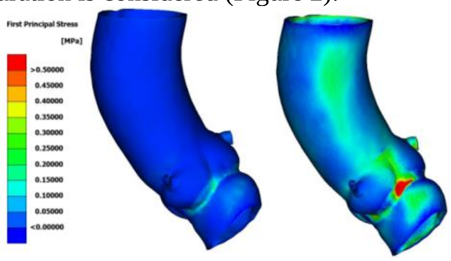

Figure 2: Maximum principal stress after device deployment without (left) and with pre-stress (right)

Discussion

The results highlight the importance of considering the zero-pressure configuration. Despite a more complex workflow, results of the simulations appear to be more reliable: a different patient who receives TAVI procedure may be subjected to a bad implantation of the device or to larger wall stress that could be correlated to complications post-implantation. If prestresses are not considered, then the simulation may not predict these bad outcomes of the procedure.

References

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