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FINITE ELEMENT ANALYSIS OF STENTLESS VALVE IMPLANT IN PATIENT-SPECIFIC AORTIC ROOT GEOMETRY

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1. Introduction

In case of aortic valve leaflet disease, the implant of a stentless biological prosthesis represents an excellent option for aortic valve replacement (AVR) in older and often sicker patients due to its several advantages (Oses, 2010). In particular, it provides a more physiological hemodynamic performance and a minor trombogeneticity without requiring the use of anticoagulants. Moreover, a continuos suture technique for implantation is adopted, which may reduce cardiopulmonary by-pass and crossclamp times (Beholz, 2006). The sizing procedure and the implantation technique are strictly related to surgeon's experience and skill. Therefore, also this treatment, like most reconstructive procedures in cardiac surgery, remains more art than science (David, 2002). The present study aims at supporting the AVR procedure planning through the Finite Element Analysis (FEA) of stentless valve implantation in an aortic root model based on patient-specific geometrical data obtained from Computed Tomography - Angiography (CT-A).

2. Materials and methods

We evaluate the implant of three different sizes of stentless tissue valves in an aortic root model directly created from the DICOM of the CT-A. Each prosthesis is placed along three different supra-annular suture lines for a total number of investigated configurations equal to nine. Firstly, we perform FEA to simulate the prosthesis placement inside the patient-specific aortic root; then, we reproduce, again by means of FEA, the diastolic closure of the valve to evaluate both the coaptation and the stress/strain state. An isotropic hyperelatic Mooney-Rivlin material is adopted to represent the material behavior of aortic leaflets and root tissue. The analyses are performed using the Abaqus Explicit solver.

3. Results and discussion

For the assumed material properties and vessel geometry under investigation, the results of the prosthesis placement allow to compare the internal stress state for each simulated combination prosthesis size/suture line, proving that both the valve size and the anatomic asymmetry of the Valsalva sinuses affect the prosthesis placement procedure. In dealing with the simulation of valve closure (see Figure 1), we are able to establish a relation between valve size, suture line and coaptation parameters, as shown in Figure 2.

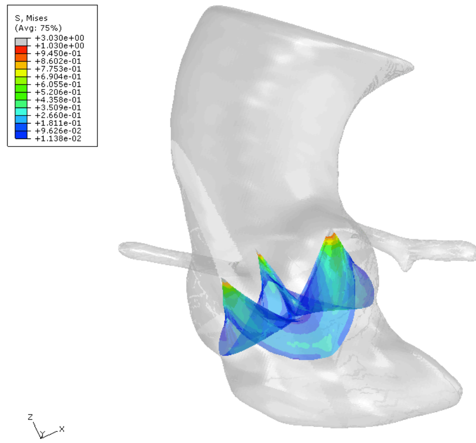

Fig.1: Results of implant simulation.

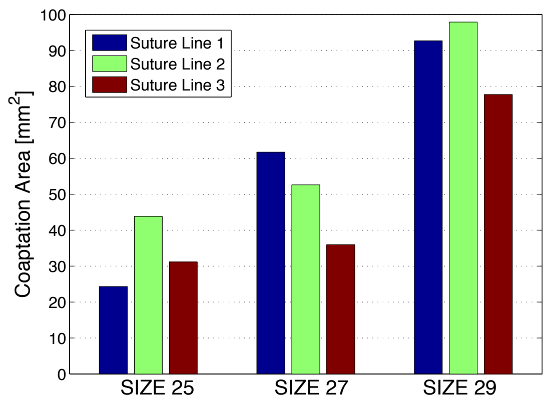

Fig.2: Post-closure comparison.

4. Conclusions

Besides the intrinsic limitation related to the complex system under investigation, we conclude that the proposed methodology offers a useful tool to evaluate the stentless valve implant aiming at anticipating surgical operation guidelines during the procedure planning.

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