Coupling *in silico* and *ex vivo* porcine model for the evaluation of biomechanical impact of TEVAR

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Abstract

The study couples the experimental and the computational approaches in an integrated *in silico* and *ex vivo* biomechanical analysis of porcine aorta. The aim of the presented work is to evaluate the mechanical impact of TEVAR on aortic structure.

Introduction

Thoracic endovascular aortic repair (TEVAR) is a surgical procedure for the treatment of aortic diseases involving the placement of one or more stent-grafts. The long-term systemic impact of endograft structure on the aortic biomechanics is still an open issue,[1] involving for multidisciplinary phenomena. In addition to systemic effects, local stiffening or severe stent-graft oversizing appear to weaken the aortic wall, and to be associated with aneurysm formation, retrograde and stent-graft-induced new dissection, or rupture.[3,4] Although several studies have been proposed using *in vivo* measurements, *in silico*, *in vitro* and *ex vivo* models, their integration could further boost the impact of biomechanical analyses for both development of novel endografts and understanding TEVAR outcomes. For this reason, aiming at the evaluation of biomechanical impact of TEVAR on aortic structure, a coupled computational and experimental analysis of porcine model have been performed.

Materials and Methods

The proposed study integrates the *ex vivo* analysis of porcine model with finite element analysis (FEA) of stent-graft deployment. In detail, optimizing the custom-made pulsatile mock loop system proposed by Lanzarone *et al.*,[5] the stiffening of the aortic structure induced by the stent-graft are investigated. Moreover, reconstructing the geometry and performing a uniaxial tensile test on porcine aortic sample the computational set-up is attained. Therefore, in agreement with the experimental test, a porcine aortic segment subjected to stent-graft implantation and subsequently to an inflation test up to systolic pressure is numerically simulated exploiting the finite element libraries of Abaqus/Explicit v. 6.16 (Simulia, Dassault Systèmes, Providence, RI, USA).

Results

To experimental investigate the stiffening of the aortic structure, intraluminal pressure was recorded in order to evaluate the pulse wave velocity (PWV) before and after the stent-graft deployment. Figure 1 shows the aortic specimen, the corresponding pressure measurement during cardiac cycle and the resulting PWV evaluation pre and post TEVAR. Moreover, Figure 2 shows the numerical possible investigation. In particular, Figure 2 depicts the stress distribution due to the stent-graft deployment.

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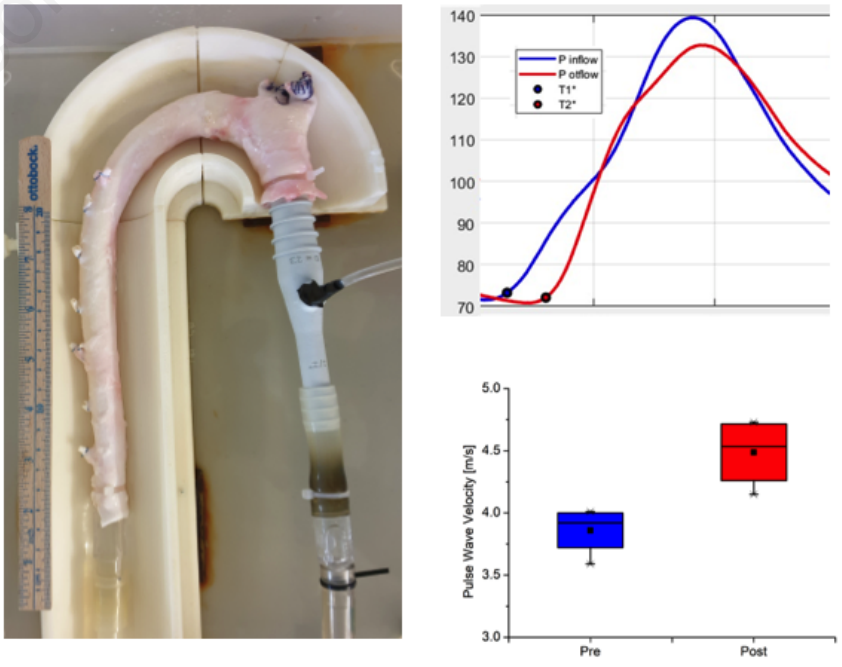

Figure 1. Left: Aortic sample in a 3D printed structure; Right: Experimental measurements of pressure during cardiac cycle (top) and pulse wave velocity (bottom).

Discussion and Conclusions

The presented study aims to clarify the impact of TEVAR on aortic physiology addressing an extensive analysis of the biomechanical aortic changes. The stent-graft-induced stiffening of arterial tissue is analyzed via the *ex vivo* measurement of pulse wave velocity. Corresponding results highlight that the presence of the stent-graft induces an increase of pulse wave velocity demonstrating the stiffening of the aortic structure. Moreover, the computational framework allows to investigate the stress localization phenomena due to TEVAR treatments. The *in silico* results, integrating the experimentally retrieved mechanical behavior of the aortic porcine model, addressing the influence of oversizing, and providing data about the stress patterns, can open to clarify the stent-graft induced patho-physiological remodeling mechanisms.

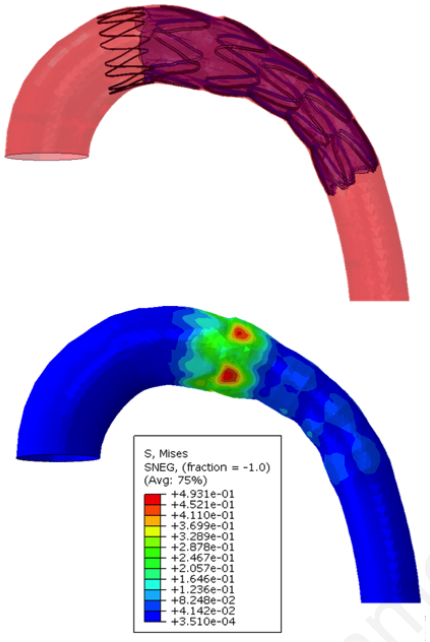

Figure 2. Distribution of Von mises stress induced by stent-graft deployment.

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