Patient-specific simulation of tools insertion before stent-graft deployment during EVAR and results comparison to 3D introperative data

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Endovascular aneurysm repair (EVAR) is a mini-invasive technique used to treat abdominal aortic aneurysms. It relies on the exclusion of the aneurysmal site by deployment of one or several stent-grafts introduced via femoral and iliac arteries. During the intervention, insertion of several endovascular tools is required to offer support and stability to the stent-graft delivery system. Among them, insertion of stiff guidewires often leads to the straightening of vascular structure. In complex anatomies, these arterial deformations may be related to difficulties to deliver the grafts or discrepancies in arterial lengths calculated from the preoperative CT-scan. Anticipation of such complications involves several factors like arteries tortuosity and angulation, level of calcification, or type of devices used and is currently based on surgical experience. We believe that mechanical finite-element simulation is a promising tool to predict these deformations and understand their effects in order to provide surgeons with objective data that would help interventions 'planning.

We developed a semi-automatic process to build a biomechanical model of the vascular structure from preoperative CT-scan data. The biomechanical model takes into account nonlinear properties of arterial wall, loading due to arterial pressure and external support provided by external tissues and bones structures. This model is then used to run an explicit finite element simulation of endovascular tools insertion with Ansys Ls-Dyna® software. Two types of tools are modeled, soft catheters and stiff guidewires. The method is presented on the case of one patient who underwent EVAR at the University Hospital of Rennes, France. During the intervention, two 3D cone-beam-CT acquisitions were performed:

- After the insertion of two soft angiographic catheters

- After the additional insertion of two stiff guidewires

Then rigid registration based on bone structures was applied to the acquired data to align with the preoperative CT-scan. 3D tools structures and arterial wall calcified plaques were segmented to allow for position measurement and comparison to simulation results.

The shape of catheters and guidewires predicted by the simulation is visually very close to the one observed on intraoperative images. 3D position error was measured along the length of the tools, it encompasses the error due to rigid registration and the simulation error. Qualitative comparison between the vascular structure deformed mesh given by the simulation and 2D angiographic images shows very similar shapes, in particular on common iliac arteries segments that underwent the largest intraoperative displacements. Arterial wall displacement is measured at several points of interest located on calcification plaques that are easily identifiable on intraoperative images. The 3D error between the position predicted by the simulation and the intraoperative data is calculated at these points

Results presented here show the feasibility of finite-element biomechanical simulations to predict the deformed position of tool and arterial wall during EVAR before stent-graft deployment for a particularly tortuous patient. A parameters sensitivity study and more patient cases are now necessary as next steps towards a patient-specific parameterization of the model.



Figure 1 3D comparison between stiff guidewires positions predicted by the simulation (in white) and real intraoperative positions (in red) (underlay: preoperative undeformed vascular structure mesh)