ON THE NEED OF A RELIABLE NUMERICAL MODEL TO SIMULATE THE LEFT ATRIAL APPENDAGE OCCLUSION: A FINITE ELEMENT STUDY

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Introduction

Left Atrial Appendage Occlusion (LAAO), a percutaneous intervention with self-expandable devices (Fig. 1a), is a viable alternative to oral anticoagulants in preventing thromboembolism for about 30% of patients affected by atrial fibrillation. Indeed, it is estimated that over 90% of stroke-inducing clots are formed in the LAA. Despite its broad application, LAA morphological complexity hinders the procedure, leading to suboptimal implants and undesirable outcomes [1]. In this context, LAAO numerical simulations represent an effective tool in guiding clinical decisions, allowing the selection of the best implant strategy. Clearly, simulation reliability is strictly related to models accuracy (both for the device and the LAA) and correctness in mimicking the implant procedure, crucial issues impacting the outcome. The available limited literature [2] aims to simulate patient-specific implant scenarios for defining the optimal device positioning, but no attention is paid to the uncertainties of their models and how they affect the results. In this scenario, the present study aims to assess the usefulness of the numerical tool for preoperative planning as long as the simulations accuracy is assured. While the device model has already been thoroughly investigated [3], uncertainties in the anatomy modeling are still an open issue and will be therefore discussed.

Materials and Methods

A reliable LAAO numerical model was developed according to the following steps.

i) A Finite Element (FE) model of the Watchman FLX device (Boston Scientific, Fig. 1a) was prepared following the pipeline in [3]. An accurate description of the Nitinol cage was adopted (material and geometry), while the covering fabric was disregarded, not affecting the device positioning.

ii) 4 patient-specific anatomies (LAA and Left Atrium, LA) were reconstructed from CT images at the maximum LA volume. If on the one hand a correct description of the geometry is achievable exploiting the images, on the other hand wall thickness and mechanical properties cannot be estimated. Thus, uncertainty quantification was performed to evaluate their influence on the implant simulation. Finally, the CT images were segmented throughout the overall cardiac cycle to introduce realistic boundary conditions for Pulmonary Veins (PVs) and Mitral Valve (MV) (Fig. 1b).

iii) Based on the real procedure [4], the steps to simulate the LAAO were: (a) *positioning* of the device crimped into a catheter modeled as a rigid cylinder, (b) *extraction* of the device from the catheter and *deployment* into patient-specific anatomies without unscrewing (to allow the clinician to check and eventually reposition the device), (c) final *release* of the device from the catheter (Fig. 1c). The outcomes of the analyses in terms of the device final configuration were discussed.

Results

The simulations proved to be a useful tool to evaluate the effectiveness of different device positionings, highlighting an interesting aspect. During the procedure, the surgeon injects a contrast medium under fluoroscopy after the *deployment* but before the *release* to assess the goodness of the device positioning. However, numerical results outlined how the deployed device configuration (what the clinician assesses under fluoroscopy) may differ from the released one (what is actually relevant for a successful implant) (Fig. 1c). Moreover, an influence of the uncertainties in describing the LAA on the final device configuration was found. The effect of boundary conditions was evident in the presence of certain LAA morphological features (e.g. small distance between MV plane and LAA implant zone), while mechanical properties affected the results in most cases.

Discussion and Conclusions

This study proved the need of a reliable numerical model to simulate the LAAO and the importance of correctly describing the phases involved in the procedure. The modeling features that impact the device final configuration and are deemed useful to accurately address clinical decisions were investigated, avoiding misleading interpretations of the outcomes.

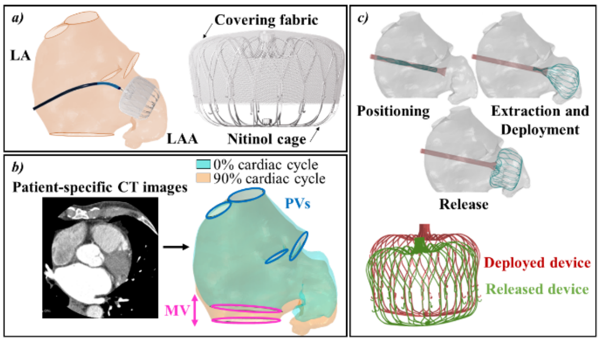

Figure 1: a) LAAO overview; b) LAA model development; c) LAAO simulation steps and device configurations post-deployment and post-release.

References

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