# A NUMERICAL WORKFLOW TO INVESTIGATE THE HEMODYNAMICS EFFECTS OF THE LEFT ATRIAL APPENDAGE OCCLUSION

**Benigno Marco Fanni (1), Emanuele Gasparotti (1), Katia Capellini (1), Francesca Danielli (2), Francesca Berti (2), Sergio Berti (3), Giancarlo Pennati (2), Lorenza Petrini (4) and Simona Celi (1)**

*1. BioCardioLab, Fondazione Toscana Gabriele Monasterio, Italy; 2. LaBS, Department of Chemistry, Materials and Chemical Engineering, Politecnico di Milano, Italy; 3. Department of Cardiology, Fondazione Toscana Gabriele Monasterio, Italy; 4. Department of Civil and Environmental Engineering, Politecnico di Milano, Italy*

## Introduction

The Left Atrial Appendage (LAA) is the main source of blood clots in patients with non-valvular Atrial Fibrillation (AF), accounting for over 90% of thrombi formation [1]. To lower the risk of cardioembolic events, LAA Occlusion (LAAO) has emerged as a key alternative treatment for patients with a contraindication to anti-coagulation therapy [2]. However, there is a risk of Device-Related Thrombosis (DRT) occurring in 2-16% of patients after LAAO [3]. In this context, numerical methods represent a powerful tool to both simulate the LAAO [4], using Finite Element (FE) analysis, and the LAA hemodynamics [5], by means of Computational Fluid Dynamics (CFD). In this work we present a patient-specific numerical workflow integrating the results of FE simulation of LAAO and CFD analysis to assess the effect of different LAAO configurations, in terms of device type and/or positioning, on the Left Atrium (LA) hemodynamics.

## Methods

The workflow is composed by two consecutive numerical simulations: FE analysis of LAAO and post-LAAO CFD simulation. LA models were obtained from Computed Tomography (CT) images of patients who underwent LAAO. The models included Pulmonary Veins (PVs) and Mitral Valve (MV). For each model, different LAAO configurations were simulated. FE simulation of LAAO was run in Abaqus, using a validated device model [4]. The device was discretized with 1D elements. The LA was meshed with 2D shell elements. LA wall thickness and stiffness were assumed from literature. Edges of MV and PVs were fixed. The deformed LA model, as result of the device expansion within the LAA, was used to define the fluid domain for the CFD analysis (ANSYS Fluent). The CFD model was meshed with tetrahedral elements. AF boundary conditions were implemented [5], using an inflow pressure condition of 8 mmHg at PVs and an outflow velocity profile at MV. An example of the workflow is reported in Figure 1, showing, first, the FE model of LAAO and, second, the post-LAAO CFD simulation.

## Results

Results of each post-LAAO CFD analysis analysed in terms of pressure, velocity, and main hemodynamic indices. Figure 2 shows the velocity field obtained from two CFD simulations of different LAAO configurations.

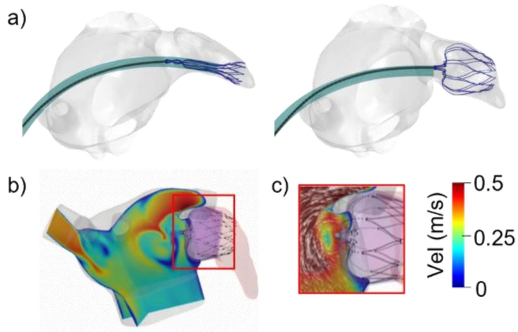


*Figure 1: FE simulation of LAAO (a) and post-LAAO CFD simulation (b) with details of local velocity field in proximity of the occlusion device (c).*

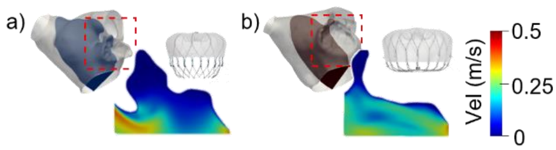


*Figure 2: Local velocity field obtained from the CFD simulations of two different LAAO configurations with Watchman (a) and Watchman FLX (b) devices.*

## Discussion

In this study an integrated FE/CFD numerical workflow was presented, with the aim to investigate the effect of different LAAO configurations in a controlled in-silico environment. Given the importance of risk stratification in the follow-up of LAAO procedure, this tool could represent a key solution in the understanding of the DRT problem. The possibility to simulate any clinical scenario, by independently setting patient anatomy, device type and positioning, would allow to explore a potentially infinite LAAO configurations and highlight the most critical scenarios from CFD results.

## References

1. Holmes et al, J Am Coll Cardiol, 64(1):1-12, 2014.
2. Berti et al, JACC Cardiovas Interv, 11(11):1086-92, 2018.
3. Sedaghat et al, Circulation, 14(5), e010195, 2021.
4. Zaccaria et al, Med Eng Phys, 82:104-18, 2020.
5. Fanni et al, Appl Sci, 10(4):1448, 2020.

## Acknowledgements

This work was funded by the Italian Ministry of Health with the project “PLACE - Planning LAa ClosurE” (RF-2021-12375208).