



Towards fast in-silico modelling to optimise the implantation of left atrial appendage occluder devices

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Background:

Left atrial appendage occlusion (LAAO) is an alternative treatment for nonvalvular atrial fibrillation patients with contraindications to life-long anticoagulant therapy. However, in a reduced number of cases, thrombus can be formed after device implantation (device-related thrombus, DRT), increasing the risk of stroke. The optimal device configuration in a LAAO procedure to avoid DRT remain undefined for each LAA morphology. In-silico fluid simulations can help to describe the patient-specific LA/LAA complex haemodynamics and then improve the device size and landing zone selection to avoid DRT. Most of these computer models are based on Computational Fluid Dynamics (CFD), which require large computational times required, hampering their use in clinical routine. Recently, faster alternatives to CFD for haemodynamic estimation have appeared, such as the GPU-based Lattice Boltzmann Method (LBM) offered by Ansys Discovery Live (ANSYS Inc.), which provide increased user-interaction capability and a possible integration into the clinical routine by reducing computational times to minutes.

Objectives:

The presented work aimed at applying fast in-silico models (i.e., GPU-based LBM solver) to predict the LAAO device configurations and subsequent blood patterns that could lead to DRT in 12 patients (6 who developed DRT and 6 who did not).

Methods:

Clinical information on the twelve studied patients who underwent LAAO was blinded to the modeler (i.e., information about which patients developed DRT). Six patients (3 DRT vs. 3 non-DRT) had an implanted Amplatzer Amulet implanted (St. Jude Medical-Abbott, St. Paul, Minnesota, United States), while a Watchman FLX (Boston Scientific, Marlborough, Massachusetts, United States) was used in the remaining six (3 DRT vs. 3 non-DRT). The clinical



data used in this work were provided by Hospital Haut-Lévêque (Bordeaux, France). The study was approved by the Institutional Ethics Committee and patients gave the informed consent. The LA were segmented from available Computed Tomography (CT) scans and 3D models generated. The same boundary conditions were employed in all performed in-silico fluid simulations: a generic pressure wave from a patient with atrial fibrillation (in sinus rhythm) for the pulmonary veins and a velocity profile from the pulsed wave Doppler echocardiography for the mitral valve. Blood flow patterns, average velocities, and vorticity were the analysed in-silico indices, as thrombotic regions are characterized by turbulent flow and low velocities. Blood flow patterns were qualitatively described based on the visual inspection of streamlines to determine the presence of swirling flow near or on the surface of the device.

Results:

In the fast in-silico simulations for DRT prediction (10 min for each simulation), the solver correctly classified 83% of the patients (10 out of 12) into healthy and DRT cases. The non-DRT group had a higher device surface velocity than the DRT group (0.25 ± 0.08 m/s vs 0.17 ± 0.02). Five out of six healthy patients had a covered pulmonary ridge (PR) whereas the PR was uncovered in five out of the out DRT cases. Moreover, the non-DRT cases presented more laminar flow in comparison to the DRT group.

Conclusion:

In-silico fluid simulations were able to predict the development of DRT in most analysed cases, showing its potential to contribute on the personalisation of LAAO device implantation. Additionally, the obtained simulations showed the relevance of covering the pulmonary ridge to reduce the presence of swirling flow with slow velocities and the risk of thrombus formation. However, further research is needed to derive more robust haemodynamic indices in a higher number of cases to confirm the potential of in-silico simulations to assess DRT risk.