In-silico analysis of left atrial appendage occluder types and configurations for the assessment of device-related thrombosis

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Background:

Atrial fibrillation (AF) is one of the most common cardiac arrhythmias and is associated with an increasing risk of stroke. To prevent thrombus formation, left atrial appendage occlusion (LAAO) is considered a suitable alternative for AF patients with contraindications for anticoagulation treatment. However, device-related thrombus (DRT) have been reported in around 1 – 7% of cases, depending on the study, in patients after percutaneous left atrial appendage occlusion. It is still under debate which device types and configurations (e.g., covering pulmonary ridge, PR) are more prone to DRT. In-silico fluid simulations are becoming increasingly useful to understand LA haemodynamics and assess the risk of DRT after LAAO.

Objectives:

The study proposes a modelling pipeline to analyse the risk of DRT in different patient-specific geometries. Several different LAAO device designs and positioning were studied in relation to their probability of developing DRT.

Methods:

Patient-specific LA geometries were extracted from Computed Tomography images of patients selected from Hôpital de Haut-Lévêque (Bordeaux). Two different LAAO device designs (disk-based Amplatzer Amulet and non-disk-based Watchman FLX) and positioning (covering and uncovering the pulmonary ridge) were analysed in regards to their possible incidence of DRT. The optimal size of the implanted device was assessed using the VIDAA platform, based on morphological measurements such as the LAA ostium and depth. A total of 24 blood flow simulations were run in the studied LA geometries using the commercial software Ansys Fluent 19.2).

Two cardiac beats were simulated considering blood flow as an incompressible Newtonian fluid in a laminar regime. In all cases the same boundary conditions were assumed: pressure inlets profile were set in the pulmonary veins; velocity outlet boundary conditions were set in the mitral valve; the MV ring plane was considered as a moving boundary. In order to evaluate the DRT, blood flow velocities and endothelial cell activation potential (ECAP) maps were computed. In addition, platelets were modelled with a discrete phase to assess their attachment near the LAAO.

Results:

Device configurations with an uncovered PR presented regions with lower average blood flow velocities, with frequent complex patterns (i.e. vortices or re-circulations). Moreover, the modelled platelets tended to be attached to the PR. Besides, low-velocity vortices were

detected in 64% and 93% of the disk- and non-disk device designs, respectively. Other thrombogenic in-silico indices such as the ECAP, were slightly higher for the non-disk devices compared to the disk-based ones.

Conclusion:

In the present in-silico analysis, covering the pulmonary ridge led to less thrombogenic patterns than uncovering it. Moreover, disk-based devices seem to have better adaptability to some LAA morphologies and, in some cases, being associated with a reduced risk of DRT. However, both LAAO designs had modelled platelets attached in the region between the device and the LA wall.