Effect of left atrial appendage occlusion for patients with atrial fibrillation during mechanical circulatory support: in-silico study

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1. INTRODUCTION

Atrial fibrillation (AF) is a common comorbidity in left ventricular assist device (LVAD) patients and has been identified as a risk factor for stroke. (Deshmukh *et al.*, 2018). Clinical studies in heart failure patients have shown reduced thromboembolic risk after occlusion of the left atrial appendage (LAA) (Deshmukh *et al.*, 2019). However potential benefits in LVAD patients are not yet fully understood. This study aims to investigate the effect of left atrial appendage occlusion (LAAO) on thrombosis-related parameters using LVAD patient-specific hemodynamic simulations.

2. MATERIAL AND METHOD

2.1 Patient Model

Left ventricular (LV) and left atrial (LA) models of an LVAD patient were obtained from computed tomography images using Mimics Research 20.0 and 3-matics Research 13.0 (Materialise, Belgium NV) (Fig. 1).

2.2 Boundary Conditions

Hemodynamics for LVAD patient were generated by lumped parameter model for AF patients and was applied for two CFD simulations with passive atrial contraction and active ventricular contraction for 8 cardiac cycles.

The Navier-Stokes equations were solved with a finite volume approach and an Arbitrary Lagrangian-Eulerian formulation in the CFD solver (FLUENT, Ansys 19.3, Pennsylvania, USA). Blood flow was modelled using the Laminar method and considered to be a Newtonian fluid with a density of 1060 kg/m3 and a dynamic viscosity of 0.0035 Pa s. The velocity and pressure boundary conditions were imposed at the inlet and outlet.

2.3 Flow Parameter Evaluation

Stasis volume (SV) was defined to highlight regions with a time-averaged velocity of less than 10 mm/s (Rayz *et al.*, 2008).

Atrial and ventricular blood washout was quantified using a virtual ink technique (Rayz *et al.*, 2010). The virtual ink was transported by the resultant flow. All fluid domains were initialized with an ink concentration of 0, with the value of 1 at inlets, representing a flow of fresh blood. The rate of LA washout was calculated by the percentage of old blood in the LA, normalized by the LA volume.

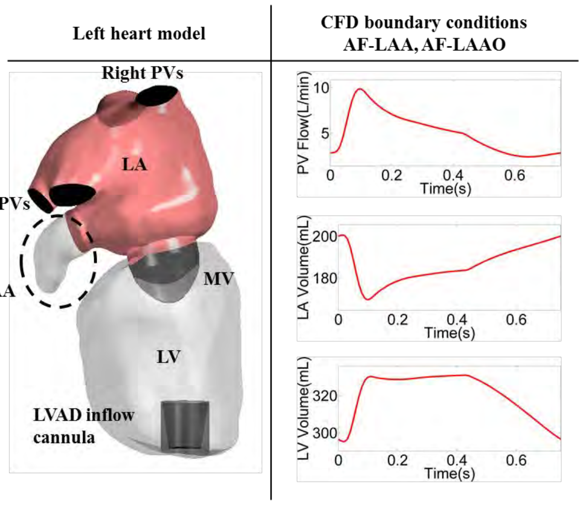

Fig. 1. Patient-specific left heart model (red geometry shows the atrium with LAAO) and CFD boundary conditions; PV: pulmonary vein, LA: left atrium, LV: left ventricle, MV: mitral valve, LAA: left atrial appendage, LAAO: left atrial appendage occlusion, AF: atrial fibrillation, LVAD: left ventricular assist device.

3. RESULTS

Occlusion of the appendage increased the overall average velocity within the LA, while comparable values were observed within the LV pre and post-LAAO. A recirculation zone with low blood velocity was observed within the LAA (Figure 2 A) and therefore after occlusion average blood velocity increased by +5%.

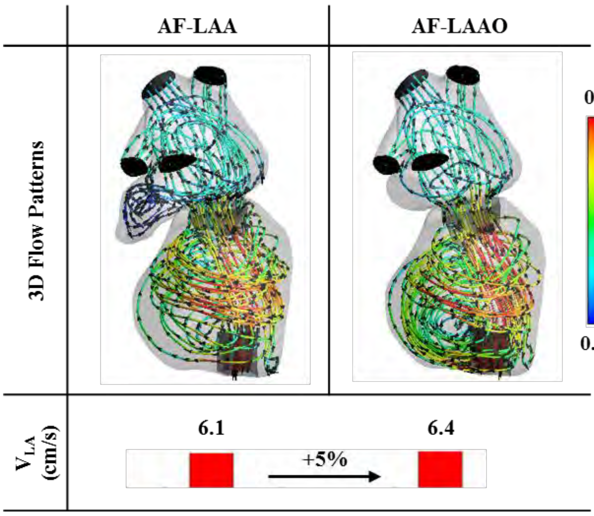

Fig. 2. Time-averaged flow streamline colored by mean velocity (V).

Appendage occlusion results in significant reduction of the stagnation volume which mainly was observed within the LAA. The reduction of 64% in stasis volume (from 6.5 to 2.3 cm^3) was observed post-LAAO.

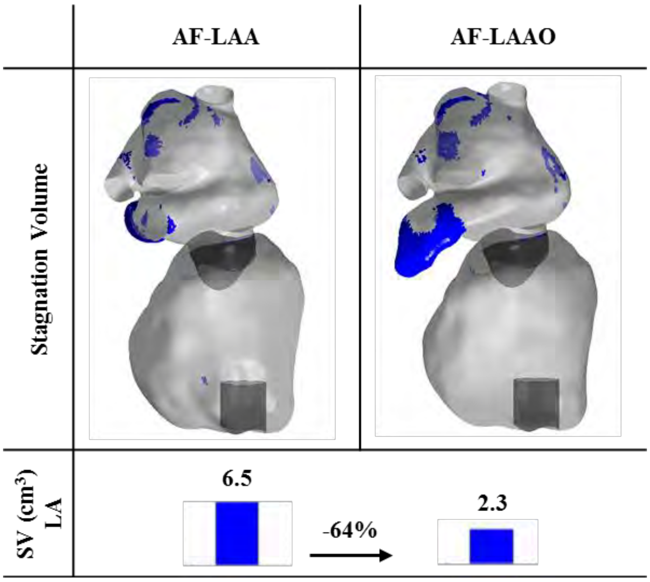

Fig. 3. Time-averaged stagnation volume (SV).

Occlusion of the appendage significantly accelerates the replacement of the old blood with the new blood within the LA. After 3 cardiac cycles the entire old blood within the LA was replaced with new blood for LAAO simulation (Fig. A and B), while without occlusion of the appendage 4.3% of the old blood remained in the atrial appendage for more than 8 cardiac cycles.

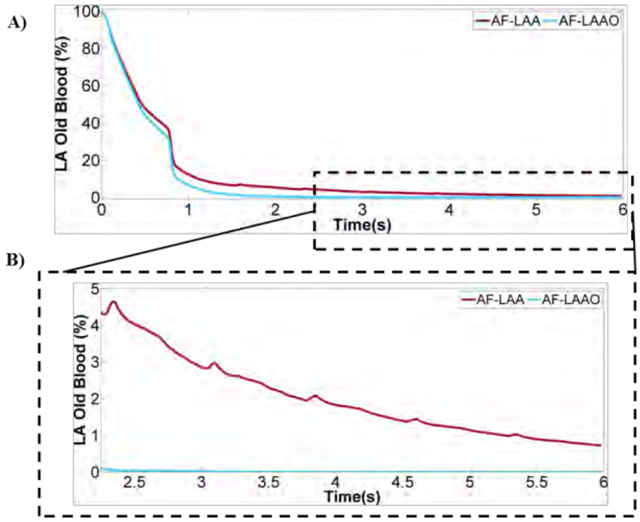

Fig. 4. Atrial blood washout A) over 8 cardiac cycles, and B) after third cardiac cycle

4. CONCLUSIONS

The results of this study showed a significant stasis volume within the left atrial appendage. These regions are known as potential sources for thrombus formation. Therefore, to reduce the stasis zones for LVAD patients with atrial fibrillation, occlusion of the appendage could be considered.

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