FSI COMPUTATIONAL MODEL OF A PATIENT SPECIFIC AAA VALIDATED BY LED ILLUMINATED PIV

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Introduction

The development and the progression of abdominal aortic aneurysms (AAA) are greatly influenced by the blood flow behavior. Important hemodynamic variables, such as the wall shear stress and the oscillatory index can be used to better understand this phenomenon. However, current imaging approaches cannot accurately evaluate these indicators *in-vivo*, numerical simulations are used instead. In order to trust the results of numerical simulation it is fundamental to properly validate them *in-vitro*. The aim of this study is to validate a fluid structure interaction simulation of a patient specific AAA by means of 2D Particle Image Velocimetry.

Methods

A patient specific aortic aneurysm phantom was manufactured via 3D printing and material casting. Sylgard 184 was chosen due to its mechanical and optical properties. The model was inserted into a novel Hybrid Mock Circulatory Loop (HMCL) that reproduces physiological flow conditions [1,2]. The outlets were connected to Hybrid-Units in order to replicate the Windkessel effect with pressure range of 0-40 mmHg.

A mixture of glycerol and water (61:39), matching the refractive index of the phantoms, was used as working fluid and the flow was seeded with 10 µm – diameter hollow spherical particles. A pulsed high-power LED (HardSOFT) and a line light were used to create a light sheet [3]. The LED was operated with a pulse width of 10 µs and a pulse separation time of 200 µs. Two regions of interest proximal to the inlet were considered. The experimental setup is shown in Figure 1.

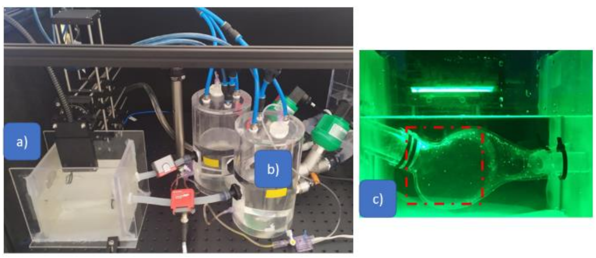

Figure 1: Experimental setup a) AAA phantom b) Hybrid-Units c) LED illuminated ROI.

A Fluid Structure Interaction simulation was set up with the CRIMSON finite element software, using the same boundary conditions of the experiment. More specifically, the same inlet flow rate and outlet pressures were prescribed. The connections to the Hybrid Units were included as additional resistors and inductors. The wall deformability was taken into account via the coupled momentum method. Three cardiac cycles were sufficient to reach a limit cycle.

Results

The velocity fields obtained from FSI and PIV were compared for different instants of the cardiac cycle. In Figure 2 we show a good agreement between them at late systole. In particular, it can be seen that the recirculation appearing during the deceleration phase is properly captured in the FSI simulation.

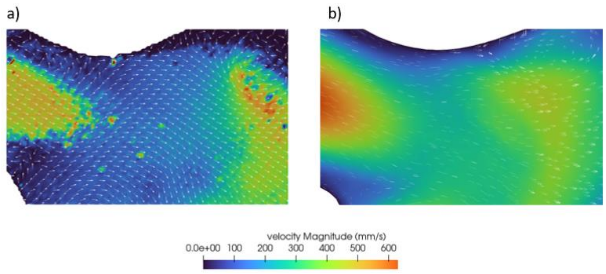

Figure 2: Comparison between the instantaneous PIV (a) and FSI (b) derived velocity magnitude.

Discussion

In this work a cost-effective LED illuminate PIV setup and a novel Hybrid Mock Circulatory Loop were used to validate *in-vitro* the results of patient specific numerical simulation. Despite a slight underestimation of the velocity magnitude, the main complex flow features occurring in the aneurysmatic sac were correctly predicted. These results confirms that FSI simulations are a reliable tool to study the fluid dynamic of AAAs.

In future investigations we will assess the influence of the boundary conditions, varying the inlet flow rate waveform and the outlets Windkessel parameters.

References

1. Bardi et al., IEEE TBME, 2022.
2. Vignali et al, ASAIO, January 12, 2022.
3. C Willert et al, Meas. Sci. Techno, 21 075402, 2010.

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