AORTIC HEMODYNAMICS EVALUATION BASED ON REDUCED ORDER MODELS: EFFECT OF INLET CONDITIONS

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Introduction

Computational fluid dynamics (CFD) assessment of patient-specific hemodynamics using full order models is a viable tool to gain insights for pathology evaluation, treatment, and prevention [1]. However, its use in clinical practice is hindered by its high computational cost in terms of infrastructures and timing. Moreover, these limitations are reflected in the difficulties to be directly translated to clinicians. In this context, non-intrusive data-driven Reduced Order Models (ROMs) represent a promising tool for facing these limitations, allowing high-fidelity and fast hemodynamic evaluation in a user-friendly setup [2,3]. In this study, a workflow to create a ROM for the evaluation of aortic hemodynamics is presented, with the specific aim to investigate the effect of inlet conditions in case of both tricuspid (TAV) and bicuspid (BAV) aortic valve.

Methods

The geometrical model is obtained by segmenting a clinical CT dataset. The workflow to create and consume the ROM is entirely developed in the Ansys suite. A 3D parametric inlet velocity profile is defined by using a two-dimensional Gaussian function to model BAV and TAV configurations. The following five input parameters are defined and used in the ROM generation (Figure 1): inlet velocity peak (v_{max} = 0 - 0.6 m/s) for profile amplitude, standard deviations along major and minor axis ($\sigma_{M,m}$ = 8 - 15 mm) for profile shape, rotation (θ = 0° - 360°) and eccentricity ($\rho/\bar{\rho}$ = 0 - 1) for profile position.

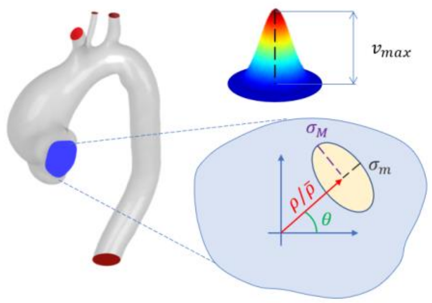

Figure 1: Input parameters.

Output parameters are velocity magnitude and direction, pressure, and wall shear stress in the whole domain. A set of 104 Design Points (DPs) is defined using an optimal space filling algorithm. For each DP, CFD results are computed, and output parameters are processed in form of snapshots. All the snapshots are then imported into the Twin Builder tool to create the ROM by compressing these data via singular value decomposition.

Results and Discussion

The results produce an interactive and high-fidelity estimation of the CFD solution. Figure 2 shows an example of the interface for ROM consumption provided by Ansys suite. ROM accuracy is evaluated by comparing the approximated solution given by the ROM and the full CFD solution calculated for the same input combination. Table 1 presents the average and maximum relative errors with respect to the full CFD for all the ROM output parameters. Errors remain below 8%, including the maximum values.

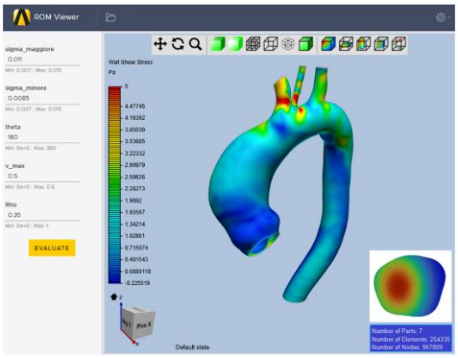

Figure 2: Example of interface for ROM consumption stage: Ansys ROM viewer is used to set input parameters and analyze output parametric results.

	Velocity	Pressure	WSS
Avg relative error [%]	0.57	0.15	0.78
Max relative error [%]	2.69	0.50	7.81

Table 1: Percentage of average and maximum relative errors for the ROM output parameters

The work demonstrates the potential to provide a user-friendly environment where clinicians can set up relevant valvular profile inputs to evaluate hemodynamic results on the aorta almost in real time.

References

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Acknowledgements

This study has been partially supported by the Marie Sklodowska-Curie grant agreement No 859836.