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Identification of the most influential factors on pulmonary artery hemodynamics using variance-based sensitivity analysis

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1. Introduction

Variance-based sensitivity analysis are useful during model personalization as they can identify which parameters are rewarding to measure patient-specifically, and which parameters can be set to a population value [2].

The variations in parameters that determine the boundary conditions of CFD simulations significantly affect the pressure and velocity fields [1]. In this study, we investigate the effects of these parameters on the hemodynamics in the pulmonary arteries to design our measurement protocol when advancing to patient-specific simulations.

2. Materials and Methods

The variance-based sensitivity analysis attributes each fraction of the total output variance to individual factors and their uncertainty, or to the interactions between input factors [2]. The individual contributions are quantified by the main Sobol index, whereas the interactions are quantified by the difference between the total and main Sobol indices.

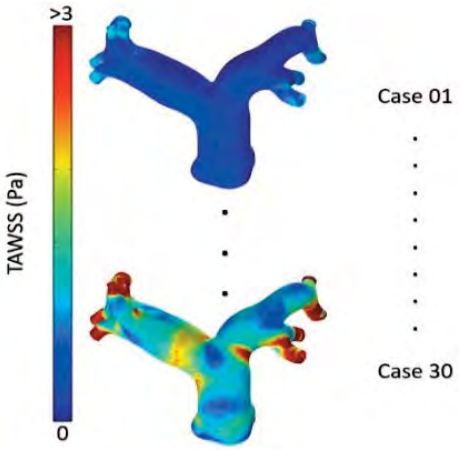
A high main index indicates that measuring this parameter is rewarding. The total index is useful to assess whether a parameter is irrelevant and can be fixed to a constant. To estimate these Sobol indices, an adaptive generalized polynomial chaos expansion method (agPCE) was applied on a 3D-CFD model [3] of the pulmonary artery. Three-element Windkessel models were coupled at the outlets and a typical inlet flow waveform was applied at the inlet. The 3D-transient model was calculated by using COMSOL. The input space for the sensitivity analysis is spanned by four uncertain inputs (Table 1). The input is subsequently sampled within these ranges using the low-discrepancy Sobol sequence via the built-in MATLAB function sobolset. Based on an a priori estimation a database of 30 samples is created.

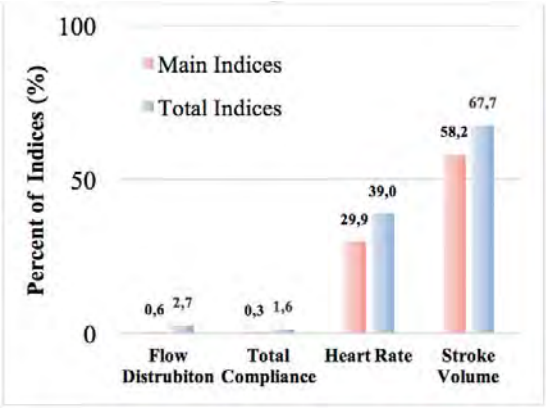
Table 1: Input parameters and their ranges

Input parameter	*Ranges*
Q_RPA to Q_LPA ratio [-]	*45-65*
Stroke Volume [ml]	*50-150*
Total Compliance [ml/mmHg] 1-4	
Heart Rate [bpm]	*60-120*

3. Results

An accurate agPCE (Q2>0.999) was found for the mean time-averaged wall shear stress (MTAWSS), which was considered as an exemplary output of interest, The Sobol indices derived from the agPCE demonstrate that the percent of main indicate for stroke volume and heart rate is much more than total compliance and flow distribution. (Figure 1, and Figure 2)





4. Discussion and Conclusions

Sensitivity analysis of the boundary condition parameters in pulmonary artery shows that MTAWSS is sensitive to stroke volume and heart rate. Also, it seems that there is not any meaningful sensitivity from total compliance and flow distribution for MTAWSS.

5. References

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