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Uncertainty Quantification in Patient-Specific Cardiovascular CFD: A Global Sensitivity Study on the Lengau Cluster

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Three-dimensional (3D) computational fluid dynamics (CFD) has emerged as a powerful tool for studying cardiovascular haemodynamics and informing the treatment of cardiovascular diseases. Patient-specific CFD models rely on boundary conditions derived from medical imaging, yet uncertainties in imaging measurements can propagate through the model and affect clinically relevant outputs such as pressure and velocity fields. To ensure that CFD-based clinical decisions are both reliable and repeatable, it is essential to quantify these uncertainties and assess the sensitivity of the outputs to boundary condition variability.

Uncertainty quantification and sensitivity analysis (UQ/SA) typically require large numbers of simulations, which makes their application challenging in 3D CFD due to high computational costs. While Monte Carlo approaches may require hundreds of evaluations, alternative methods such as generalized polynomial chaos expansion reduce the number of runs but remain computationally demanding.

In this study, we present a global UQ/SA framework implemented on the Lengau Cluster for coarctation of the aorta, a common form of congenital heart disease. The uncertain inputs are the lumped parameters of the 3-Element Windkessel Model, prescribed at the outlets to represent distal vasculature. We evaluate how variability in these parameters impacts pressure and velocity fields, with the objective of improving the robustness and clinical utility of patient-specific CFD simulations.

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No

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Yes

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