When the "Boundary" is Critical: Defective/Missing Data for Computational Hemodynamics

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Abstract

The pathway of computational hemodynamics from being a proof-of-concept research tool to a clinical-routine support is not complete, but we are not so far. Multiple challenges need to be addressed for the dream to come true. We mention particularly (i) the efficiency of solvers for large volume of patients; (ii) the reliability of simulations in patient-specific settings.

Form the clinical standpoint, the most important factors in a numerical simulation are the geometry and the boundary conditions. Imaging devices and image processing tools are currently at an excellent quality level to provide accurate morphological reconstructions of patient-specific computational domains. The numerical treatment of patient-specific boundary conditions, on the contrary, is much more troublesome . The challenges come from the fact that we have several diverse scenarios in clinical settings and the identification of standard data-retrieval procedures to be used to generate boundary conditions for numerical simulations is not easy. Most importantly, available data are almost invariably not enough to make the mathematical problems to solve well-posed. Arbitrary assumptions need to be postulated to complete defective (or even totally missing) data. In this arbitrariness, we can loose reliability of the simulations for clinical purposes. After empirical approaches exploited in the biomedical engineering literature, it is evident the mathematically sound approaches for filling the gap may provide reliable solutions. However, the trade-off between computational costs and efficiency is still to be found.

In this talk, we will give a general overview of possible approaches for prescribing boundary conditions in defective/missing data scenarios, suffering from the "image-legacy problem" (= doctors store many nice images, they do not record corresponding boundary

data, so we need to run simulations on real geometries with no data). In this context, we introduced also the so-called "geometrical multiscale" approach [1]. We address possible practical approaches to fit within clinical timelines working on real cases for aortic pathologies and coronary disease simulations [2, 3]. As the definition of a general standard "boundary-condition protocol" is currently out of reach, this talk will just outlines possible practical solutions.

We also address open challenges for setting up efficient numerical solvers that may run in small facilities, reasonably available to hospitals and healthcare institutions for the clinical routine. Special solvers designed for incompressible fluids in pipe-like domains - based on the so-called Hierarchical Model Reduction approach - will be recalled.

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