Methodology, Experience and Recommendations for Determining Parameters in Closed Loop Cardiovascular Simulations

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ABSTRACT

As our capabilities for simulating cardiovascular systems becomes more advanced, we naturally tend towards constructing systems which contain increasing numbers of parameters [1]. This increase in complexity creates great opportunities for novel applications, but it simultaneously presents new challenges. While the potential experimental data becomes simultaneously richer, for any particular simulation study we find that the data which is actually available will contain insufficiencies and typically be incomplete. Methods are required in order to compensate whilst preserving as much patient-specific character as possible.

As the model complexity increases, algorithms which we have previously used to tune parameters in order to match patient data become more difficult to use, or simply inapplicable; for example, in cases where patient-specific heart models or closed-loop [2, 3] circulatory modelling is performed. In the former case, these difficulties arise due to the biophysical coupling between the ventricle and the aorta limiting our usual ability to control peak systolic or pulse pressure by adjusting the systemic compliance. In the latter, notions such as total blood volume in the system become implicitly defined by the initial conditions, which is in opposition to the open-loop situation. Furthermore, tuning becomes more difficult as the effects of changing parameters propagate throughout the closed loop.

In the present work, we review the strategies which have been found to be robust when working with simpler classes of models; describe when and why they may not be appropriate in more advanced settings, together with some alternatives; and we explain some methods that we have found useful when only partial or insufficient patient datasets are available. We focus in particular on the creation of patient-specific heart models, and on understanding which parameters should be adjusted in order to achieve target systolic and diastolic aortic pressures.

We illustrate the methods with some examples taken from our recent modelling work.

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