AKADEMIE WISSENSCHAFTEN UND KÜNSTE NORDRHEIN-WESTFALEN

Marek Behr

Model Development and Optimal Design for Heart Assist Devices

Ferdinand Schöningh

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1. INTRODUCTION

The computational analysis of blood flow in medical devices holds the promise of new highly biocompatible designs that extend the lives of patients suffering from cardiovascular diseases without compromising their quality of life. Just as fluid flow simulation has been slowly supplanting the need for costly experiments in the aerospace and marine industries, to name a few, it is hoped that wider adoption of computational models in the biomedical industry will greatly reduce the need for in vivo animal trials and further reduce the risk of testing in humans.

There are multiple scientific obstacles that have slowed down the development and application of simulation technology to the cardiovascular system and blood-handling devices. The behavior of blood, both as a flowing medium and as a living organism, is extremely complex, and thus not comparable with the simple air or water flows that need to be considered in other engineering fields. The variability of blood behavior between humans and animals, between different patients, or even for the same patient at various disease stages, reduces the predictive power of simulation, and makes stochastic approaches and uncertainty quantification particularly important.

Simulation efforts are underway concerning most aspects of cardiovascular system:

- heart-assist devices,
- arterial vessels for patient-specific surgery planning and risk assessment,
- artificial heart valves, both mechanical and bioengineered,
- heart muscle function,
- arterial stents including drug elution to prevent restenosis, and,
- hollow fiber oxygenators for lung support.

In any one of these application areas, a myriad physicochemical processes need to be considered, including the following: