Impact of Turbulence Modeling on Hemodynamic Risk Indicators for Aortic Dissection: a Quantitative Comparison of Predicted Risk Sites with Laminar Flow Model

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Abstract

Aortic dissection is one of the most dangerous cardiovascular conditions, it demands early diagnosis and fast treatment to improve patient outcomes. The pathology is characterized by a tear in the inner layer of the aorta, allowing blood to enter and create a false lumen between the inner and middle layers of the aortic wall. Early diagnosis and patient specific risk assessment of aortic dissections pose challenges for clinical treatment and appropriate interventions. Numerical simulation based on patient specific geometries promise to support the clinical analysis and improve systematic risk assessment of aortic dissections. Since Reynolds numbers in the aorta, especially in the aortic arch reach values of 3.500 and more in physiological settings, numerical hemodynamic modeling necessitates the consideration of turbulence models. In this study, the impact of turbulence modeling based on Smagorinsky Large-Eddy-Simulation model [1] on clinically significant hemodynamic risk indicators is investigated. The main focus for this study lies in the comparison of frequently studied surface risk parameters for prediction of mechanical wall damage caused by complex flow patterns such as Oscillatory Shear Index [2]. The predictive capacity of the turbulent approach is compared against laminar flow modeling across a series of patient-specific geometries. We analyze these patterns across the ascending aorta wall surface, the aortic arch, and the proximal descending aorta wall to account for localization-specific disease patterns. To evaluate the clinical relevance of turbulence modeling, simulations are performed on geometries in pre-dissection state with known positions of the dissection localization based on patient data. This enables an assessment of the predictive accuracy of laminar and turbulence models by comparing simulated risk sites with patient-specific dissection sites, thereby demonstrating whether complex turbulence models offer added value in a clinical context.

References

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