Abstract of the Doctoral Thesis

Diagnostics of hemolysis risk in atherosclerosis - numerical analysis and experimental studies

Cardiovascular diseases are one of the leading causes of death in 21st-century society. One of the most common cardiovascular diseases is coronary artery atherosclerosis. Accumulating cholesterol causes significant narrowing of arterial vessels, which increases the risk of hemolysis due to high shear stresses acting on erythrocytes in the area of narrowed arteries.

In the course of a doctoral dissertation, a new numerical model of blood rheology was developed based on the population balance of red blood cell aggregates, which takes into account the process of mechanical hemolysis. Furthermore, based on medical imaging data, a series of 3D models of stenosed arteries were developed. These models were later used to prepare numerical meshes for CFD simulations and to develop vascular system phantoms for both PIV studies and training materials for physicians.

A series of CFD simulations have demonstrated the influence of the shape of the atherosclerotic stenosis on the maximum shear stresses, which are associated with the risk of hemolysis in the vessels. It was shown that the risk of hemolysis is highest in small vessels where sudden and significant narrowing of the artery lumen occurs. The impact of physical activity and coexisting hypertension on the increased risk of hemolysis was determined. The obtained results were validated using 3D-printed artery phantoms produced on a Form 3B+ printer, utilizing equipment for micro particle image velocimetry (μPIV). Additionally, 3D printing was used to develop a training station for angioplasty with stent implantation for training procedures for interventional radiologists and surgeons.

In summary, through a series of articles, numerical and experimental modeling of the phenomenon of hemolysis in the arteries of patients with atherosclerosis was presented, which allowed for the development of guidelines for physicians and tools for effective treatment planning to reduce the risk of perioperative complications.

Keywords: hemolysis, atherosclerosis, computational fluid dynamics, 3D printing, particle image velocimetry