EXPERIMENTAL AND NUMERICAL ANALYSIS OF THE PARTICLE- AND CELL MIGRATION IN GAP-LIKE FLOWS OF VENTRICULAR ASSIST DEVICES

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Introduction:

Patients with advanced terminal heart failure require a donor heart or a technical solution of a ventricular assist device (VAD). A VAD pumps blood from the left ventricle into the artery. To generate the required pressure, the impeller rotates at several thousand revolutions per minute. These high rotational speeds and speed gradients affect the blood. Blood consists of a low-viscosity plasma and high-viscosity cellular components. To minimise damage or activation of the blood components, it is important to numerically identify areas of high stress in a VAD (e.g. bearing regions or side chamber of radial impellers). In these simulations, a single-phase blood analog fluid is used, which has a similar density and viscosity as blood. Nevertheless, this assumption can lead to a deviation, especially in narrow gaps. In gaps between 7-300 µm, the particles migrate to the center of the vessel, and a low-density layer of plasma forms between the wall and the cells. It is known in medicine as the cell-free layer (CFL). After the successful optical analysis of the particle migration, the influence of particle migration in a stationary channel under the flow conditions of a VAD gap (Re ~ 100; 150µm) was investigated both experimentally and numerically

Methods

To better understand the flow in narrow gaps, these flow conditions were adapted to a stationary narrow gap-like flow of ventricular assist devices. Optical analysis, wall shear stress, and pressure measurements were used to study particle migration and flow behavior in these confined spaces. Various Reynolds numbers were tested (50-150), which represent typical flow conditions that prevail in VAD gaps. Various blood with different hematocrits and blood analog fluids were used. In addition, a numerical model was developed based on the optical measurement and particle distribution over the channel height. This takes into account the effect of cell migration based on the change in viscosity over the height of the channel.

Results

A cell-free layer was found in all tested particulate fluids, leading to a reduction in stress and pressure loss compared to single-phase fluid without a cell-free layer. The numerical results were compared with the previously measured experimental results with particle-laden blood analog fluids and with newly recorded blood measurements with particle volume fractions up to 5% (Re = 50 to 150). A good agreement was found between the numerical simulations and the experiments on wall shear stress and pressure losses. Furthermore, it can be seen that the shear stress in the fluid decreases as well.

Discussion

The results in our experimental setup led to the hypothesis that the CFL-formation and stress reduction are also present in the narrow gaps of VADs. A satisfactory agreement was attained between the experimental observations and the numerical results. Now it is possible to predict numerically the impact of particle migration on the flow.