FLOW VISUALISATION AND SIMULATION IN REALISTIC ANEURYSMS GEOMETRIES TO DETERMINE THE RISK OF RUPTURE

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Introduction

Determining the risk of rupture of intracranial aneurysms is a great challenge. Geometrical parameters, such as sac volume and size, are commonly used to define a proper medical treatment. In recent years, hemodynamics parameters, such as shear stress and oscillatory shear index, have gained attention to predict the aneurysm rupture [1]. In the last few years, numerical flow simulations in complex biological structures have also gained considerable attention [2]. However, the primary challenge is the validation of the numerical procedures due to the complexity to measure velocity and shear stress and compare them to the computed results. The main goal of the present work is to classify geometrical and hemodynamic parameters to predict the possible rupture of the aneurysm using numerical simulations, tested with experimental values.

Methods

Numerical simulations were performed using realistic geometries. Aneurysms 3D models were reconstructed from the Aneurisk project [3]. The blood was modelled as a Newtonian fluid with constant properties. As a first approximation, the arterial walls were rigid, and no-slip boundary condition was considered. An oscillatory velocity profile was imposed at the inlet and the κ-ε turbulence model was employed.

An experimental setup was designed to validate the numerical simulation. Dye injection technique and tracking particles technique were employed to visualise the flow distribution in the 3D printed aneurysms. A camera (Sony RX0 II F4.0) was used to capture videos, which later were processed to track particles and compute flow velocity and streamlines.

The 1R machine learning algorithm was used for classifying the geometrical and hemodynamic parameters.

Results

Using the dye injection and tracking particles techniques, the generated transparent model visualised the flow patterns with a regular camera. The obtained videos are clear enough to track particles and calculate velocities. The hemodynamics parameters were obtained through numerical simulation, using OpenFOAM. The IR analysis used the following hemodynamic parameters: wall pressure and wall shear stress, oscillatory shear index (OSI), residence time, gradient oscillatory number (GON), vorticity, Q criterion, stokes number for particles, and enstrophy to classify the aneurysm in combination with the traditional parameters. The algorithm inferred five rules for predicting the rupture of an aneurysm based on the variable O_MinSize (size ratio, sac diameter, sac height, parent vessel ratio) and a reliability of 82.8% was obtained.

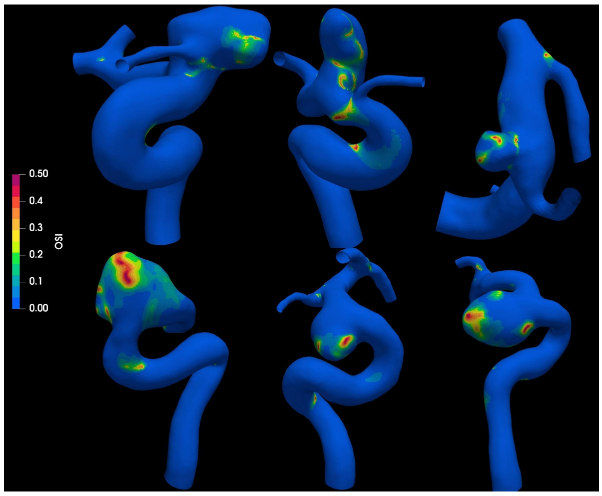

Figure 1: OSI obtained through numerical simulation for six aneurysms.

Discussion

The proposed visualisation technique has shown promising results, as well as the IR algorithm as a prediction tool for aneurysm rupture. The performed numerical simulations showed good agreement with the experiments (qualitatively).

References

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