Images based CFD applied in a case of cerebral aneurysm

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1. Introduction

As the medical imaging techniques progress, the use of Computational Fluid Dynamics (CFD) is becoming increasingly present in biomedical research. Now, arterial diseases are responsible for half of all deaths in the western world [1]. Thus justifies the use of CFD in the study of arterial diseases, in particular of aneurysms, a formation of an irreversible arterial bulge.

Two questions come out, when speaking of CFD in biomedical applications:
- What are the main steps that lead to an image-based CFD simulation?
- What information does image-based CFD provide when applied in a case of cerebral aneurysm?

2. Image processing

Starting from datasets obtained through Magnetic Resonance Imaging (MRI), the process described below (Figure 1) enables the creation of a three-dimensional mesh of the aneurysm.

![Fig. 1: The model reconstruction](image)

3. Modelling

The assumptions made and the models chosen for the numerical steady state simulation are summarized in Table 1.

<table>
<thead>
<tr>
<th>Fluid model</th>
<th>Blood is a Newtonian, homogeneous fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>Rigid vessel walls satisfying a no-slip condition</td>
</tr>
<tr>
<td>Boundary conditions</td>
<td></td>
</tr>
<tr>
<td>Inlet</td>
<td>Parabolic velocity with a mean value of 34 cm/s</td>
</tr>
<tr>
<td></td>
<td>Pressure: zero gradient</td>
</tr>
<tr>
<td>Outlet</td>
<td>Velocity: zero gradient</td>
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<tr>
<td></td>
<td>Uniform pressure of 0 Pa</td>
</tr>
<tr>
<td>Flow model</td>
<td>Turbulent</td>
</tr>
</tbody>
</table>

4. The Results

The simulations done with OpenFOAM, after post-processing with Paraview, gave the following results (see Figures 2-5):

- A wall shear stress threshold located at the neck of the aneurysm
- Velocity streamlines that show strong recirculation inside the aneurysm and some turbulence.
- The velocity distribution explains the WSS threshold location (Figure 5)

Fig. 2: Wall shear stress distribution (front view)

Fig. 3: Wall shear stress distribution (view from the back)

Fig. 4: Velocity streamlines

Fig. 5: Velocity represented on a slice of the aneurysm

Conclusion

→ Running a computational fluid simulation by using MRI images requires four main steps: the image processing, the modelling of the problem and finally the CFD simulation itself followed by the post-processing.

→ Applying the steps to a cerebral aneurysm model provides information on:
  - The location and value of the wall shear stress threshold
  - The maximal velocity and the velocity shape

Hence, this work testifies to the fact that CFD simulations provide a good insight into the hemodynamics around patient specific arterial diseases such as an aneurysm.

References:


University of Glasgow, charity number SC004401