Cerebral Stents: A Performance Measure of Wall Shear Stress for Robustness

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Cerebral stents are used to restore blood flow through an artery with an aneurysm, while having an additional aim of encouraging a coagulating flow condition within the aneurysm. This means that the blood flow characteristics through the stent wall to the aneurysm need to be markedly different to those close to the artery wall, and by implication, so does the effect of the stent design. This is a challenge beyond satisfying the general requirements for stent performance.

Design optimisation methods have developed to address variability, in particular Robust Engineering Design (RED) whose significance is in its aim to render the design insensitive to noise. A stent design must function despite noise in the form of variations in artery and stent geometry, and inlet flow characteristics. Selecting an appropriate performance measure is also important for successful RED and while most reported work is based on the topological distribution of Wall Shear Stress (WSS), in this paper we compare the use of a performance measure based on WSS distribution as a means of assessing stent design performance. WSS is the measure commonly used to indicate the interaction between fluid and wall but it is a broad brush approach that loses fidelity close to the wall.

The given models were meshed and the flow characteristics simulated in Fluent. Meshing the models satisfactorily was more complicated than expected since the shape of the artery and the stent were very complex and surface models were only supplied for the VISC06 exercise. Therefore, fully 3D CV subdivisions were derived from surface modelling for CFD simulations. In the present work, a step further is made from the VISC06 requirements in that non-Newtonian fluid behaviour was taken into consideration in the CFD analysis.

Apart from the full simulation of the stented models, an alternative approach was also tried where the stent was substituted by a thin porous medium, thus simplifying the geometry to be investigated. The aim was to check whether the use of a porous media in place of the stent could substitute for the overall effect of the stent inside the aneurysm region. This would allow the simulations to be simplified by only having a simple porous layer instead of the complex stent geometry. A possible shortcoming, of course, would be to lose information about the local flow behaviour in the proximity of the stent wires. For the porous medium, the equation used for computing the pressure drop across it, was essentially Darcy's Law combined with an additional inertial loss term.

Within the challenge of VISC06 more specific aspects of the problem may be identified. The effect of the thin stent wires on local flow and the influence of inflow angle to the stented zone are of interest:

- local flow around wires because this is where low oscillatory shear flows are associated with disease,
- inflow angle because this represents a noise factor between patients that impinges differently upon a given stent design and affects WSS distribution.

Qualitative graphical WSS output and conventional basic summary measures of WSS are a limited means of comparing the three stent designs and for driving design improvement, whereas WSS distributions provide clearer insight and are a more informative quantitative measure of performance. Although in this study RED analysis is not considered, the authors believe that such a performance measure, based on the distribution of WSS in the aneurysm region, would be very valuable for the robust design assessment of cerebral stents.