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LARGE EDDY SIMULATION IN INTRACRANIAL ANEURYSMS: SHOULD TRANSITION BE CONSIDERED IN NUMERICAL MODELING?

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In case of weakened vessels within the human brain, intracranial aneurysms may form. These remodeled arteries are characterized by a balloon-like shape and it is estimated that they occur in 2-5% of the western population. If the degraded vessel layers are unable to resist the pulsatile blood flow, a rupture may occur leading to a subarachnoid hemorrhage. The consequences are severe in most of the cases including death or irreversible disabilities.

Since until now the rupture risk assessment is poorly understood, numerical methods that are well known from many fields of engineering are applied to this medical problem in order to predict rupture probabilities. However, several assumptions are used to reduce the complex biochemical interactions and therefore allow generating hemodynamic parameters with reasonable computational costs. The major simplifications include 1) the treatment of vessels as rigid walls, 2) assuming a constant viscosity instead of a non-Newtonian fluid, 3) neglecting pressure variations and coupling behind outflow regions and 4) assuming laminar flow behavior, since only low Reynolds numbers are found in cerebral arteries.

The latter point is addressed in this study since several groups detected recently increased frequencies or instabilities throughout the cardiac cycle [1, 2, 3, 4]. In order to analyze a possible influence of transitional flow locally, two intracranial aneurysms have been numerically investigated by comparing laminar computations and Large Eddy Simulations (LES). An idealized basilar tip aneurysm and a patient-specific middle cerebral artery aneurysm were chosen, respectively. The computations are based on high-quality block-structured meshes and have been carried out with a sufficiently small time step in order to capture all temporal changes. The resulting velocity fields are evaluated component-wise as well as with Fast Fourier Transformation and wavelet analyses [5].

The first results indicate that increased frequencies are visible throughout the cardiac cycle within the aneurysm sacks but not as high as predicted by other groups (see Figure 1).

Further investigations are necessary and the comparison between both approaches will be presented during the conference. Then, conclusions can be drawn whether standard methods can be applied further on, or if certain conditions with respect to temporal/spatial resolution and transition modeling need to be considered within future numerical studies.

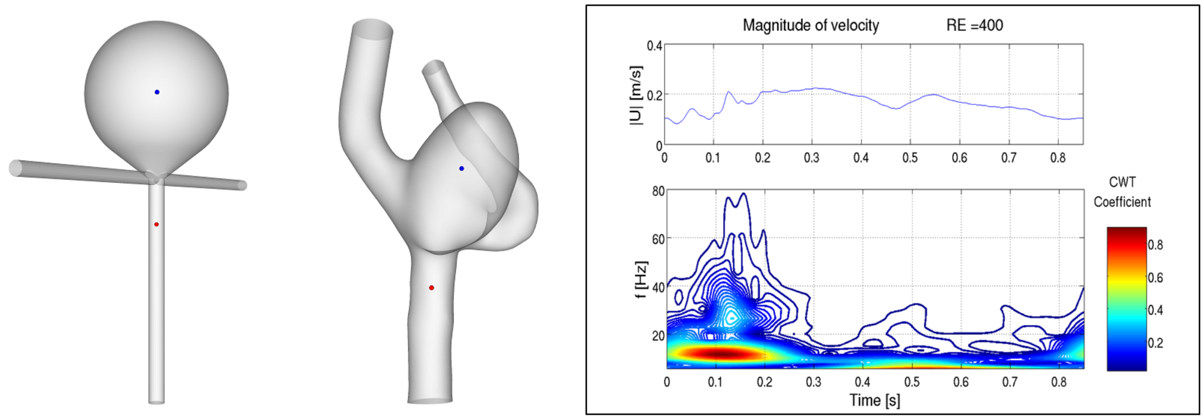

Figure 1: Representation of the investigated intracranial aneurysm models (left), Example of a wavelet analysis indicating increased frequencies at different times within the cardiac cycle (right).

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