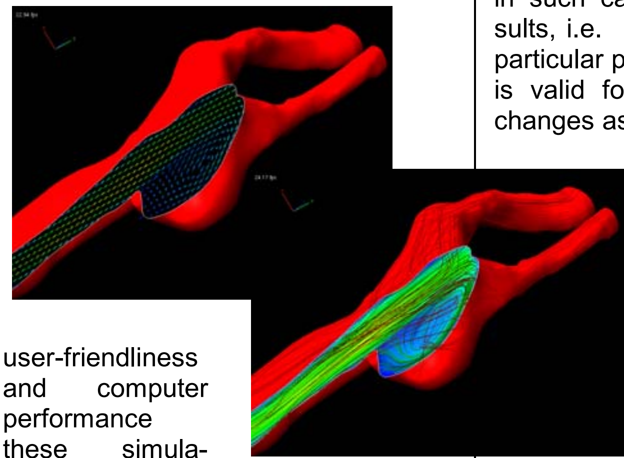
swift

Blood Flow Analysis

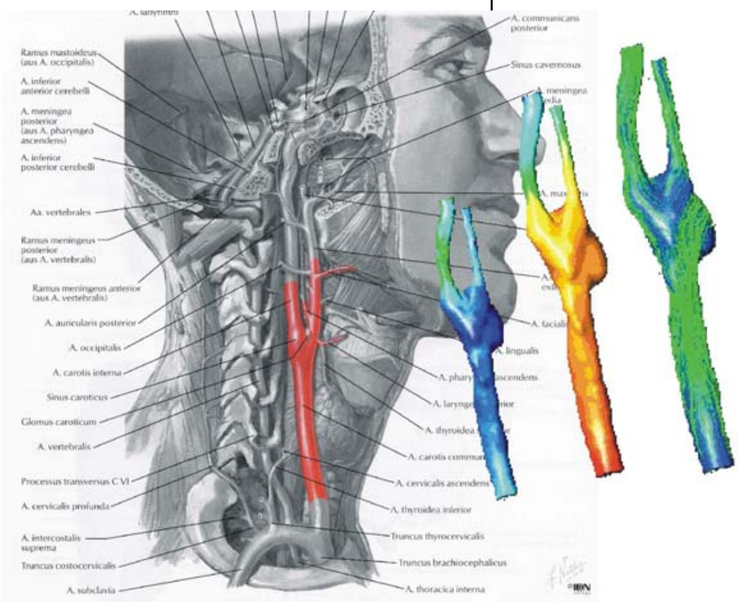
SWIFT is a powerful multi-purpose thermofluid software package and represents the new generation of 3D Computational Fluid Dynamics. SWIFT combines an intuitive user interface, fast meshing and solution algorithms and well validated physical models. Numerical investigations of blood flow take full advantage from that combination.

Vascular diseases such as atherosclerosis and aneurysms are becoming frequent disorders in the industrialised world due to excess sedentary and rich food. Causing more deaths then cancer, cardiovascular diseases are the leading cause of death in the western world. Significant research efforts are made to investigate detailed effects of vascular diseases and their resulting consequences in the diminution of health.

Since more than a decade numerical simulations of blood flow inside vessels are supporting these investigation. Due to an increase in software user-friendliness and computer performance these simulations are gaining more and more practical importance.



The influence of geometrical changes of the vessels, e.g. by stenotic lesions, aneurysmen, or by-pass operations, are subject of these investigations. A number of special features have to be considered to calculate blood flow accurately. Mainly the transient flow behavior due to the heart cycle and the non-Newtonian flow effects, especially the dependency of the blood viscosity on the local shear rate, have to be mentioned in that respect.



The shape of the vessels are significantly different in many areas from one human being to an other. A detailed geometrical representation of the particular situation is required in such cases to achieve useful results, i.e. the vessel geometry of a particular person has to be know. This is valid for pathological geometrical changes as well.

The entire process and the subsequent flow calculation and discussion of results are demonstrated on the basis of bifurcation areas, arteria carotis communis with arteria carotis interna and externa, with a pathological dilatation and arteria vertebralis dextra and sinistra with ateria basilaris.

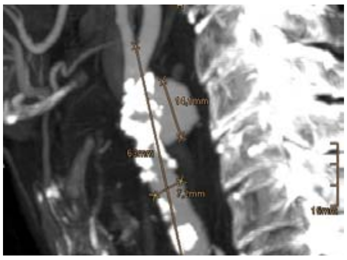
Workflow

A successful analysis incorporates a continuous chain of working steps. The process starts with (non-intrusive) Computer Tomography (CT), in order to account for a particular vascular physiology. The CT data are processed further and triangulated surface data in 3D STL format are generated automatically. The surface data are imported by a STL filter into the SWIFT package. Dedicated algorithms are applied for the smoothing of the surface. The mesh generation is performed with AVL FAME, a world-class preprocessor, which generates automatically meshes with a high degree of hexahedral elements, local refinements and body fitted boundary layers. Based on the generated mesh, the flow is simulated by the SWIFT solver. Advanced result evaluation, including streamline representation and movie generation is directly enabled within the SWIFT package.

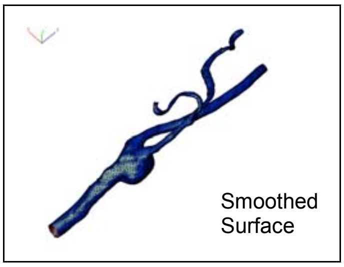
Sales & Marketing, Tel.: +43 (316) 787-1851, Fax: +43 (316) 787-1462, Email: ast@avl.com

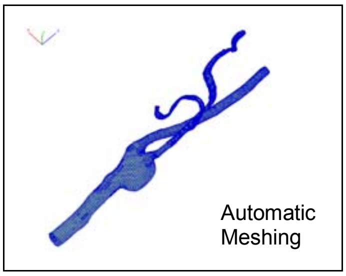
The workflow for blood flow analysis at one glance:

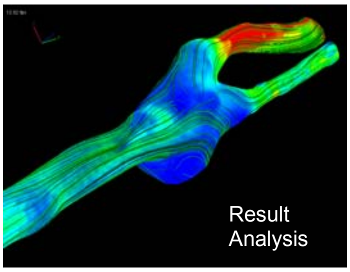
- Computer tomography
- Automatic generation of surface data
- Smoothing of the surface
- Automatic generation of the computational meshes
- Transient flow simulation considering heart cycle and physical properties of blood
- Result assessment, e.g. the influence of stenotic lesions, aneurysmen, by-pass operations



Computer Tomography







Workflow from Computer Tomography to Flow Results

Mathematical Model

The momentum and continuity equations in time-dependent and three-dimensional formulation are solved during the solution process.

Following Newtons law the stress-components are functions of the local velocity gradients and the molecular viscosity. For Newtonian fluids the viscosity appears as a constant.

Many publications show that the viscosity of human blood is influenced by a variety of effects . For the calculations presented here the effect of shear-thinning was taken into account. This effect is originated by the aggregation of the RBC (called Rouleaux-effect). This aggregates are destroyed at high levels of shear rates resulting in lower viscosities. In vessels with large diameters this effect is the main cause for the Non-Newtonian behavior for human blood.

To define the dependency between viscosity and the local shear rate, the equation of Cross was used.

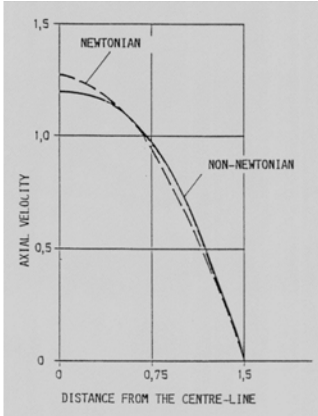
$$\eta = \eta_\infty + \frac{\eta_0 - \eta_\infty}{F_{(Y)}}$$

$$F_{(Y)} = 1 + A \cdot \gamma \qquad A = 8$$

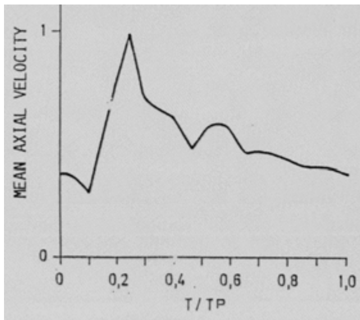
$$\eta_0 = 1.3 \cdot 10^{-1} \frac{Ns}{m^2}$$

$$\eta_\infty = 5.0 \cdot 10^{-3} \frac{Ns}{m^2}$$

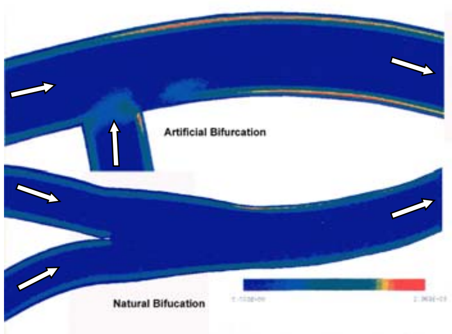
For test purposes a 10 mm long straight part of the middle cerebral artery was investigated. Steady Newtonian and non-Newtonian calculations were performed for this part of the artery to assess the differences under well defined conditions. Higher viscosities of the non-Newtonian case in the middle of the atery are reflected in the velocity profile by a reduction of the center velocities. The gradient of the axial velocities at the wall are higher for these cases.



Typical heart-cycles were used for further calculations as inlet conditions.



The blood flow in a natural junction, arteria vertebralis dextra and sinistra with ateria basilaris is compared with the flow in an artificial junctions, resulting from a by-pass operation. Shear rates in the artificial bifurcation are rather high compared to the natural bifurcation and indicate potential areas for the generation of stenotic lesions.



Distribution of Shear Rates

Sales & Marketing, Tel.: +43 (316) 787-1851, Fax: +43 (316) 787-1462, Email: ast@avl.com