On the numerical analysis of coronary artery wall shear stress

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On the Numerical Analysis of Coronary Artery Wall Shear Stress

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Objective

To determine whether the time-averaged wall shear stress in the coronary artery can be accurately modelled by means of steady flow of a Newtonian fluid through a rigid geometry.

Geometry

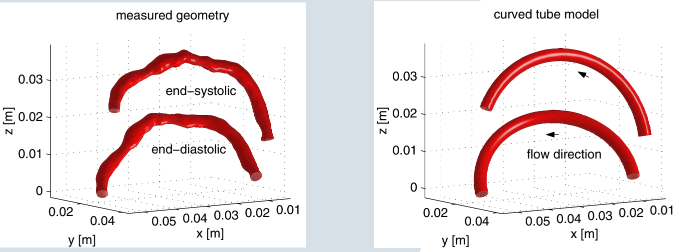

Figure 1 *Measured geometry (left) and curved tube model (right) of the right coronary artery.*

Motion and flow rate

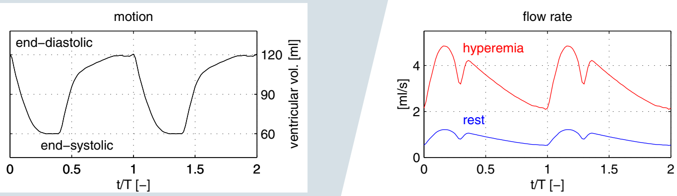

Figure 2 *Motion interpolation function (left) and flow rate wave form (right), after Berne and Levy (1967).*

Viscosity modeling

The shear thinning viscosity of blood is modeled using a Carreau-Yasuda model: $\dfrac{\eta - \eta_\infty}{\eta_0 - \eta_\infty} = \left[1 + (\lambda\dot{\gamma})^a\right]^{\frac{n-1}{a}}$.

Viscosity model	η
Shear thinning	$\eta(\dot{\gamma})$
Unscaled Newtonian	η_∞
Scaled Newtonian	$\eta(\dot{\gamma}_c)$

Table 1 *Viscosity models, with $\dot{\gamma}_c$ the characteristic shear rate in 2D Poiseuille flow.*

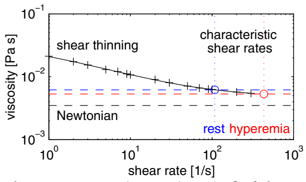

Figure 3 *Viscosity of blood (cross: measured; solid: fit), after Thurston (1979).*

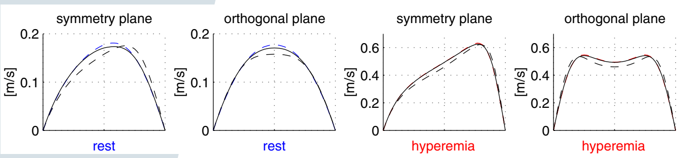

Figure 4 *Axial velocity profiles for steady mean flow through the rigid end-diastolic geometry (dash-dotted: unscaled Newtonian; dashed: scaled Newtonian; solid: shear thinning).*

Velocity distribution

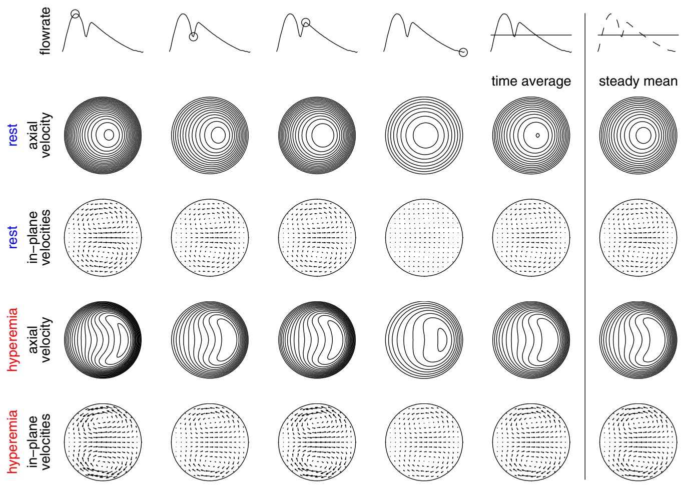

Figure 5 *Contour and vector plots of the axial and in-plane velocities at 0.75 tube length distance from the inflow: moving/shear thinning (extrema and time average) vs. rigid/Newtonian (steady mean).*

Wall shear stress distribution

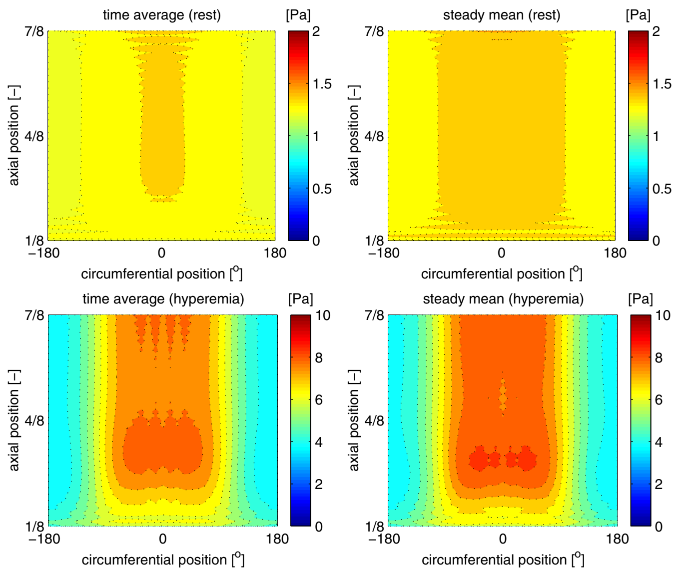

Figure 6 *Wall shear stress contours (outer bend at 0°): moving/shear thinning (time average) vs. rigid/Newtonian (steady mean).*

Conclusion

The time-averaged wall shear stress distribution in a right coronary artery model applying time varying, non-Newtonian flow in a moving and deforming geometry can be approximated well by modeling steady mean flow in the end-diastolic geometry using a shear-rate scaled Newtonian viscosity.

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