Supplementary Material

# Description of viscous energy loss rate

Viscous energy loss rate (VELR) represents the rate of flow mechanical energy loss due to friction between two adjacent fluid layers moving at a different velocity (i.e., fluid shear).[1] Assuming blood as an incompressible and Newtonian fluid, VELR per unit volume can be calculated as,

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|  | $$VELR=\frac{1}{2}μ\sum\_{i=1}^{3}\sum\_{j=1}^{3}\left(\frac{∂u\_{i}}{∂x\_{j}}+\frac{∂u\_{j}}{∂x\_{i}}\right)^{2}-\frac{2}{3} μ\sum\_{i=1}^{3}\left(\frac{∂u\_{i}}{∂x\_{i}}\right)^{2}$$ |  |

where $μ$ indicates the dynamic viscosity and $u\_{i}$ indicates the velocity component along $x\_{i}$ direction where $x\_{1}$, $x\_{2}$ and $x\_{3}$ correspond to the Cartesian axes $x$, $y$ and $z$, respectively. A dynamic viscosity of 3.2 cP was assumed for blood in the aorta.[2]

# Description of vorticity

Vorticity represents the angular velocity vector of a fluid element under rotation present when flow becomes spatially nonuniform and increases as flow exhibits stronger turbulent or faster vortical flow motion. Vorticity ($ω)$ is a vector quantity calculated by taking the curl to the velocity vectors,

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| --- | --- | --- | --- |
|  | $$ω=\left[\begin{matrix}\frac{∂u\_{3}}{∂x\_{2}}-\frac{∂u\_{2}}{∂x\_{3}},&\frac{∂u\_{1}}{∂x\_{3}}-\frac{∂u\_{3}}{∂x\_{1}},&\frac{∂u\_{2}}{∂x\_{1}}-\frac{∂u\_{1}}{∂x\_{2}}\end{matrix}\right]$$ |  |  |

where first, second and third element corresponds to the vorticity components along $x\_{1}$, $x\_{2}$ and $x\_{3}$ axis, respectively.

1. P. K. Kundu and I. M. Cohen. Fluid Mechanics, fourth edition. Elsevier; 2008. p. 112-113.

2. N. Westerhof, N. Stergiopulos, M. I. Noble, et al. Snapshots of hemodynamics: an aid for clinical research and graduate education: Springer; 2018.