2nd European Fluid Dynamics Conference (EFDC2)
26 – 29 August 2025, Dublin, Ireland

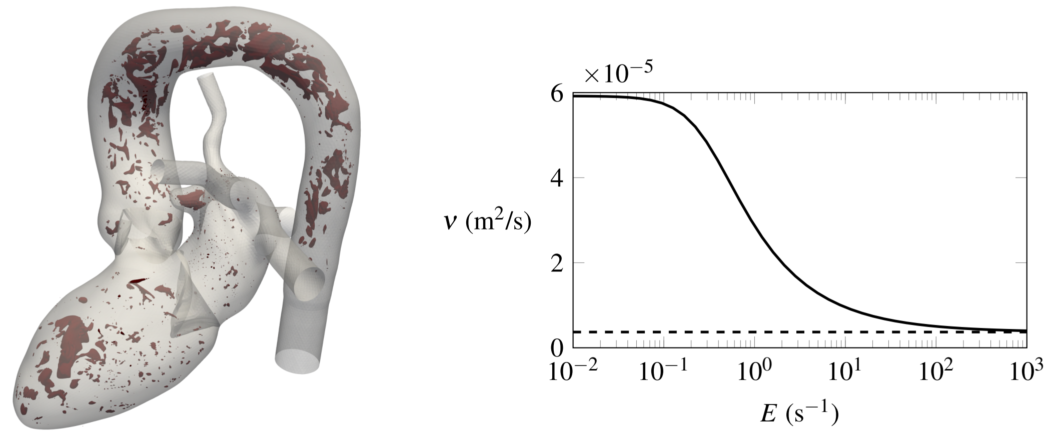
Does non-Newtonian blood rheology matter in large vessels and heart chambers?

Valerio Lupi[*], Filippo Caruso Lombardi[*], Martino Andrea Scarpolini[*†], Fabio Guglietta[‡†], Roberto Verzicco[‡*§] and Francesco Viola[*]

Numerical simulations of blood flow allow computing hemodynamic quantities that are often inaccessible through *in vivo* or *in vitro* measurements, providing cardiac surgeons with valuable information on cardiovascular diseases. However, computational models usually involve several hypotheses, which can affect the reliability of the results. One of the crucial assumptions concerns the constitutive relation of the blood.

Blood is a biphasic fluid that exhibits a shear-thinning, viscoelastic, thixotropic behaviour. Non-Newtonian effects can become particularly relevant even in large vessels and heart chambers in the presence of diseases, stagnation regions, and pulsatile flow (see Figure 1a). Nevertheless, blood is often regarded as a Newtonian fluid in the literature, especially for flows in large vessels[1], and accounting for its non-Newtonian properties is still a debatable topic in the scientific community. Previous studies have addressed this research question, assessing the influence of different rheological models on the hemodynamics of prosthetic valves[2],arteries[3], the left ventricle[4], and the left atrium[5]. Notwithstanding, to the best of the authors' knowledge, there is no study investigating the non-Newtonian behaviour of the blood in the left heart considering the interplay between electrophysiology, structural mechanics and fluid dynamics.

To overcome this gap, we assume a Newtonian and a Carreau (non-Newtonian) rheological model for the blood viscosity (see Figure 1b) and perform numerical simulations of the fluid-structure-electrophysiology interaction (FSEI)[6,7] in the left heart. We assess the influence of the constitutive relation of the blood on several key hemodynamic quantities, e.g. the wall shear stress and the hemolysis index.



(a) (b)

Figure 1: (a) Isosurfaces of $\nu = 2.5\nu_\infty$ in the left heart. (b) Kinematic viscosity ν as function of the norm of the strain rate tensor E according to the Carreau model (——), uniform viscosity ν_∞ for the Newtonian blood model (- - - -).

This work was supported by the European Research Council (ERC) under the European Union's Horizon Europe research and innovation program (Grant no. 101039657).

[*] Gran Sasso Science Institute (GSSI), L'Aquila, Italy
[†] INFN Tor Vergata, Rome, Italy
[‡] University of Rome Tor Vergata, Rome, Italy
[§] Physics of Fluids Group, University of Twente, Enschede, The Netherlands

[1] Verzicco, *Journal of Fluid Mechanics* **941**, P1 (2022)
[2] De Vita et al., *Theoretical and Computational Fluid Dynamics* **30** (1), 129–138 (2016)
[3] Lynch et al., *Scientific Reports* **12**, 20568 (2022)
[4] Doost et al., *Computer Methods and Programs in Biomedicine* **127**, 232–247 (2016)
[5] Gonzalo et al., *International Journal for Numerical Methods in Biomedical Engineering* **38** (6), e3597 (2022)
[6] Viola et al., *European Journal of Mechanics - B/Fluids* **79**, 212–232 (2020)
[7] Viola et al., *Physical Review Fluids* **8** (10), 100502 (2023)