3D pulsatile blood flow in aneurysms accounting for non-Newtonian effects

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Abstract

We investigate in silico the pulsatile blood flow in arteries with an aneurysm formation under normal and abnormal flow conditions. We use a recently proposed integrated elasto-viscoplastic constitutive model coupled with thixotropy (TEVP) [1,2] which accounts for the RBC aggregability through a kinetic equation that describes the level of blood structure at any instance and the viscoplasticity at stasis conditions. The model parameters are based on steady, simple shear, and transient multi-shear rheometric experiments for human physiological subjects with normal blood aggregability. We investigate blood flow under sinusoidal and experimentally determined waveforms with different frequencies, amplitudes, and patterns, providing a thorough parametric study. Predictions are also provided for the hemodynamics of pulsatile flow in the case of atrial fibrillation, the most chronic arrhythmia [3–5]. As pulse frequency increases, the variation on structure parameter becomes smaller, a tendency of a recirculation formation inside the aneurysmal dome appears and significantly high values of Wall Shear Stress (WSS) are noticed around the neck of the aneurysm. With an increase in pulse amplitude, blood is getting softer and easier to flow, while WSS inside the aneurysm dome remains low enough to promote a potential growth or rupture, as low wall stresses have been correlated with these processes [6,7]. The curvature of the parent vessel of the aneurysm affects the dynamics of the flow since a different behavior throughout the cycle is exhibited. In contrast to the WSS, the predicted total stress magnitude for the curved vessel is higher than the one for the straight vessel. For a normal experimentally-measured waveform (NW) the WSS on the aneurysm wall is higher than that for a case with atrial fibrillation (AFW). However, it is still capable of contributing to further aneurysm growth. Blood is quite structured in the case of AFW, meaning it is more difficult to flow, especially inside the aneurysmatic region and thus the intra-aneurysmal velocity is quite low.

References

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