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Flow structures and red blood cell dynamics in arteriole of dilated or constricted cross section.

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Abstract

Vessel with 'circular' or 'star-shaped' cross sections are studied, representing respectively dilated or constricted cases where endothelial cells smoothly line or bulge into the lumen. Computational haemodynamics simulations are carried out on idealised periodic arteriole-sized vessels, with red blood cell 'tube' hematocrit value =24%. A further simulation of a single red blood cell serves for comparison purposes.

The bulk motion of the red blood cells reproduces well known effects, including the presence of a cell-free layer and the apparent shear-thinning non-Newtonian rheology. The velocity flow field is analysed in a Lagrangian reference frame, relative to any given red blood cell, hence removing the bulk coaxial motion and highlighting instead the complex secondary flow patterns. An aggregate formation becomes apparent, continuously rearranging and dynamic, brought about by the inter-cellular fluid mechanics interactions and the deformability properties of the cells. The secondary flow field induces a vacillating radial migration of the red blood cells. At different radial locations, the red blood cells express different residence times, orientation and shape.

The shear stresses exerted by the flow on the vessel wall are influenced by the motion of red blood cells, despite the presence of the cell-free layer. Spatial (and temporal) variations of wall shear stress patters are observed, especially for the 'circular' vessel. The 'star-shaped' vessel bears considerable stress at the protruding endothelial cell crests, where the stress vectors are coaxially aligned. The bulging endothelial cells hence regularise the transmission of stresses on the vessel wall.