Blood flow over microscopic ridges on coronary artery surface

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https://doi.org/10.1098/rsif.2020.0327

Background & Aim

The surface roughness of the coronary artery is associated with the onset and progression of atherosclerosis and other cardiovascular diseases (CVD). To date all computational models which investigate macroscopic coronary blood flow assume the walls to be completely smooth. The present study implements a microscopic roughness profile into the artery to determine the impact on the near-wall blood flow, and investigate how our approaches to modelling blood can be improved.

Methodology

Ex Vivo optical microscopy was used to obtain surface height profiles in 2 directions. These were combined to create a 3D rough surfaced segment of artery. Several approaches to modelling blood were compared, from simple constant viscosity, to red blood cell (RBC) and plasma multiphase models. Physiological boundary conditions were applied, over 7 cardiac cycles (Using 300 Cores for 6 days per model). With the focus being the comparison between the rough/smooth segments, and the performance of each blood model.

Results

Interestingly, whilst averages over the rough/smooth segments were in strong agreement to clinical studies, the rough surface experiences a much wider range of important parameters relating to CVD, with maximum wall shear stress (WSS) being 6 Pa on the rough, and only 3 Pa on the smooth surface. The ‘valleys’ of the roughness are prone to stagnation, pathologically low WSS and extreme fluctuations in haematocrit (RBC concentration), with no clear correlation between height and haematocrit.

Conclusions

Whilst an entirely rough surfaced 3D coronary model is still computationally unfeasible, the impact of surface roughness has been demonstrated significant on common parameters assessed in relation to atherosclerosis, with some blood models shown to be unsuitable for such studies. Now such an implementation has been provided, integration into other models for studying rough artery/device interaction in stents/catheters or predicting sites of plaque formation based on platelet adhesion in low-shear environments are all exciting clinically relevant prospects…