TOWARDS PREDICTIONS OF HAEMORRHAGIC VERSUS THROMBOEMBOLIC EVENTS FROM ROTARY BLOOD PUMPS.

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Introduction

Haemorrhagic and thromboembolic events are post-surgical complications in LVAD patients. Fluid dynamic stresses cause activation and damage to blood components, creating a delicate balance between bleeding and clotting. A numerical model may enable a better understanding of the propensity for bleeding and clotting in patients with different LVADs.

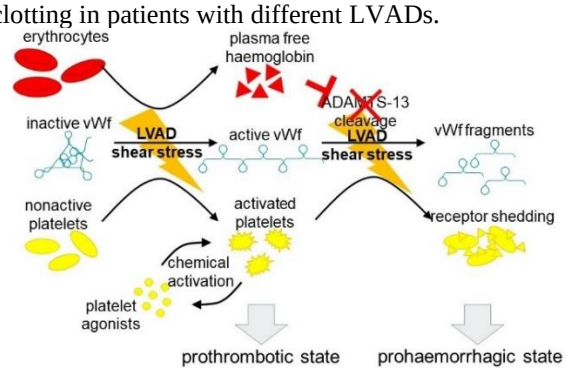

Figure 1: Fluid shear stress leads to prothrombotic and prohaemorrhagic states in patients with blood pumps.

Methods

Eight steady state, convection-diffusion-reaction equations were solved for: free haemoglobin (pfHb), von Willebrand factor (vWf) (collapsed, unfolded and fragmented forms) [1], platelets (nonactivated, activated and receptor shed) [2,3], and an example platelet agonist. Source terms for pfHb, mechanical activation and receptor shedding from platelets, used power law functions of shear stress and time. Chemical platelet activation was proportional to agonist concentration above a threshold. Rate constants for vWf unfolding and collapsing were dependent on the local flow type: rotating, shearing or extensional. Fragmentation of unfolded vWf occurred above a critical shear depending on the pfHb concentration [4]. Platelets attached to the walls according to a thrombus susceptibility potential modified from [2]. Blood flow was solved in Ansys Fluent with reaction equations implemented as User Defined Functions. Individual models were first compared with literature results from stenosis-like geometries [1,5,6]. The model was then used to estimate clotting in the HeartMate II and compared with [7].

Results

Haemolysis results predicted the right order when a shear stress threshold (250 Pa) was introduced (fig 2). Results for shear induced vWf unfolding were in good agreement with the literature in both symmetric (fig 3) and asymmetric (not shown) stenosed flows. Qualitative agreement in regions of high platelet deposition was found (fig 4). The relative numbers of platelets deposited in the different regions of the HeartMate II was similar to the relative numbers of thrombus formations (note the bearing was not modelled in this work.)

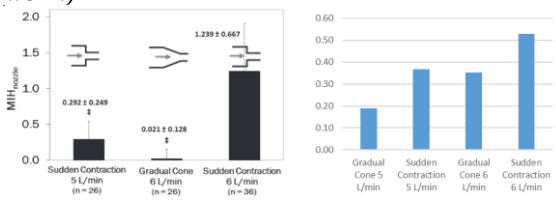

Figure 2: haemolysis in nozzle [5] (left), model (right)

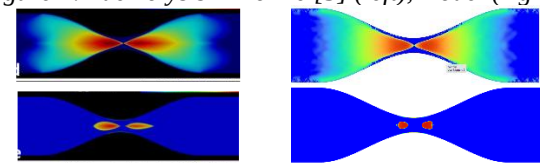

Figure 3: flow type (top) and vWf unfolding rate (bottom) from literature [1] (left) and our model (right)

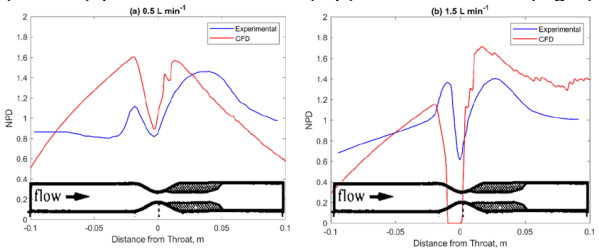

Figure 4: platelet deposition comparison with [6]

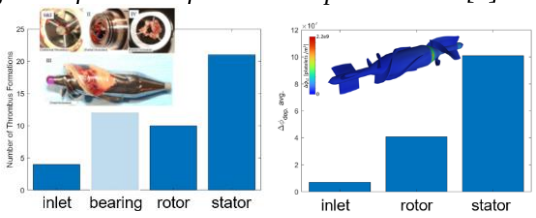

Figure 5: clinical thrombi [7] (left) compared with platelet deposition in model (right)

Discussion

While the model still requires some tuning, it was able to predict the LVAD region with most thrombi. In future the model could be used for design optimization.

References

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