EVALUATION OF COMPUTATIONAL MODEL FOR HIGH SHEAR THROMBOGENESIS
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Introduction
Current state of the art thrombosis models cannot accurately predict thrombosis in complex, high shear flows similar to those seen in rotating blood pumps. [2]
We adapt the Goodman, et al. [1] model to a high shear rotating flow and evaluate its predictive capabilities. Adaptations include:
• Method of inputting initial species concentration
• Wall boundary assignments
• Shear activation of platelets in the bulk flow
• An annular gap of 360 µm was used to induce a shear of up to 10,000 s⁻¹.
• A 130 µm² longitudinal channel was machined every 10 degrees into the inner cylinder.
• This geometry was designed to induce thrombogenesis and mimic the extreme ranges of shear rates that can occur in cardiac assist devices.

Computational Methods
• Laminar, unsteady, 2-D solver
• Outer wall is defined as a rotating wall
• Structured mesh with a grid size of 3 µm² at the inner wall and 10 µm² at the outer wall
• Periodic boundary conditions were used to reduce the computational domain
• Species transport was modeled using the coupled convection-diffusion equation
• Blood was modeled as a Newtonian fluid
• An ideal geometry with smooth surfaces was assumed

Experimental Methods
• Hepranized bovine blood was exposed to shear for 120 seconds.
• The test section was constructed with polycarbonate.
• After exposure to shear, inner cylinder was rinsed 3 times with saline then fixed and dyed with a modified Wright stain.
• Digital microscopy was used to visually inspect for attached platelets.

References

Computational Results
The top row are results for a shear of 5000 s⁻¹ and the bottom row is for 10000 s⁻¹. Figures 2A, 2B, 3A and 3B are contour plots of percent thrombus growth. The four plots are on the same scaling showing the fluid (blue) and increasing thrombus growth (red is the highest). Figure 2C and 3C show the entire channel and are contour plots of rate of platelet attachment.

Experimental Results
Microscopy was used to inspect the inner cylinder after each test. The same 20 random points were inspected after each test. A clot value (explained below) was assigned to each of the 9 locations shown in figure 1. Tables 1 and 2 are histograms of these results.

Conclusion
The experimental results show that more platelet coverage occurred for a shear of 5000 s⁻¹. The clear difference between thrombus growth in areas 2 and 8 was not seen in the experiments. While this thrombogenesis model shows promise, further research is needed for this model to be applicable to cardiac assist devices. The model would greatly benefit from further experimentation that investigated the nature of platelet transport in high shear flows.

Clot Value: 0 - No platelets in field of view (FOV) 1 - Scattered platelets, but no connection between individual clusters. 2 - Clusters connect to form larger group. Groups usually form long chains. Most of FOV is polycarbonate. 3 - Clusters are 3D and very little polycarbonate can be seen. 4 - Large 3D cluster that is dark in the center.

Table 1. Histogram of clot value for the 9 locations for a shear of 5000s⁻¹

Table 2. Histogram of clot value for the 9 locations for a shear of 10000s⁻¹