CALIFORNIA STATE SCIENCE FAIR
2007 PROJECT SUMMARY

Name(s)
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Project Number
S0215

Project Title
Better Stents: Simulating the Effect of Obstructions in Vascular Blood Flow on Coagulation

Abstract

Objectives/Goals
My objective is to develop and implement a model of blood coagulation in the vascular system from which the relative clotting hazards of various obstructions may be predicted. Stents, which have found widespread use in treating arterial blockage, have increasingly been implicated in blood coagulation in the vascular system leading to catastrophic consequences like stroke. I hypothesized that larger or sharp-edged obstructions will lead to quicker clotting while smaller or rounded profile obstructions will lead to slower clotting.

Methods/Materials
2.5 GHz Personal Computer with 512 MB of RAM.
The simulation, using Visual C++, was carried out in 2 steps.
(I) Compute flow field according to Navier-Stokes equations: 1) Establish 200 X 50 grid. 2) Load wall geometry - assign a state (liquid, wall/liquid, inlet/outlet) to each node. 3) Load boundary conditions. 4) Compute velocity and artificial density at next time step. 5) Update grid with new velocity and artificial density values. 6) Repeat 4 & 5 until velocity and artificial density have converged satisfactorily.
(II) Model clot formation: In each time interval, 1) Assign velocity to each platelet per stream velocity. 2) Advance each platelet. 3) If new speed differs from old by more than 40%, activate with probability p_shear. 4) If an active platelet is near a wall and not near a deposited platelet, deposit with probability p_adhere. 5) If an active platelet is near a deposited platelet, deposit with probability P_adhere. 6) If an inactive platelet is near a wall, deposit with probability r. 7) Remove already-deposited platelets with probability q. 8) Add N randomly-distributed platelets at inlet. 9) Assess and repeat 1-8.

Results
The flow calculations were successful. The clotting effects found are qualitatively consistent with general expectations of clot formation. Further, larger or sharp-edged obstructions resulted in more rapid clotting while obstructions that are smaller or have a rounded profile resulted in slower clotting.

Conclusions/Discussion
The results from the simulations performed in this project offer support for our hypothesis. We have produced a faithful account of blood flow around vascular system obstructions. Combining this with a model of clot formation, sharp edges and protrusions toward the center of the vessel appear to be factors promoting clot formation. These results may provide guidance for safer stent design in the future.

Summary Statement
This project used the Navier-Stokes equations of fluid dynamics to simulate the effect of obstruction in vascular blood flow - whether due to imperfections in the vascular walls or the presence of an object such as a stent - on coagulation.

Help Received
Parents drove me to the library.