Measuring and modeling blood flow in malaria

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When people have malaria, they are infected with Plasmodium parasites, which enter the body from the saliva of a mosquito, infect cells in the liver, and then spread to red blood cells. Inside the blood cells, the parasites replicate and also begin to expose adhesive proteins on the cell surface that change the physical nature of the cells in the bloodstream.

Experiments show that infected red blood cells are stiffer and stickier than normal ones -- in the later stages of the disease, up to 10 times stiffer. They also tend to adhere to the endothelial cells lining the vasculature, affecting the normal blood flow. This explains some of the common symptoms of malaria, such as anemia and joint pain.

Sticking to the walls of blood vessels is a survival mechanism for the parasite. In order to develop completely, it needs several days inside a red blood cell. Even though parasitized cells are nearly invisible for the immune system, they may be destroyed in the spleen while circulating freely in the bloodstream.

Doctoral student Dmitry Fedosov and Brown University professor George Karniadakis are studying how malaria infections affect the physical properties of red blood cells, and alter normal blood flow circulation. In particular, they examine an increase in blood flow resistance, and dynamics of infected cells in the bloodstream.

The researchers present these findings today at the 62nd Annual Meeting of the American Physical Society's (APS) Division of Fluid Dynamics.

They also monitor the mechanical properties of infected red blood cells by measuring membrane temperature fluctuations, and through the response of a "microbead" that is attached to the cell and twisted. The measured properties are then used in modeling the flow of red blood cells in people infected with malaria. They also collaborate with the group of professor Subra Suresh at MIT, who obtain experimental measurements of the properties and the flow of healthy and infected cells.

"Our model predicts the dynamics of malaria-infected RBCs in the bloodstream, which anticipates the possible course of the disease," says Fedosov.

Recently they found that temperature fluctuations of infected red blood cell membranes measured in experiments are not directly correlated with the reported cell properties, hence suggesting significant influence of metabolic processes. They measured an increase in resistance to blood flow in the capillaries and small arterioles during the course of malaria and found that parasitized red blood cells have a "flipping" motion at the vessel wall that appears to be due to stiffness of the infected cells. The developed models will aid to make realistic predictions of the possible course of the disease, and enhance current malaria treatments.

More information: The talk "Multiscale modeling of blood flow in cerebral malaria" by Dmitry Fedosov, Bruce Caswell, and George Karniadakis is at 6:12 p.m. on Sunday, November 22, 2009. Abstract: meetings.aps.org/Meeting/DFD09/Event/111038

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