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Titre: Development of simulation methods to study blood flow and transfer at different scales.

Résumé: Blood is a bio-physical system that has been studied for many years yet many of its behaviors are still not understood. Its mechanical behavior (non Newtonian viscosity) as well as the complexity of oxygen transfer by red blood cells are still active research subjects. Consequently, many research groups focus on studying blood experimentally, theoretically and numerically. The numerical simulation of blood is a challenge for several reasons.

Blood is intrinsically a multi-scale problem. A red blood cell has a length of about 7 microns. Suspensions of red blood cell flow in vessels having very wide range of diameters (typically from 5 to 400 microns). The mechanical behavior of individual blood cell and the interactions between cells at different scales generate a rich variety of rheological behaviors. Moreover, blood vessels are organized in tree-like or mesh-like structure. The organization of the vessel network has a strong influence on the distribution of oxygen from blood vessels to the tissues. Thus, the simulation of the vascular network is also a multi-scale problem.

During this presentation, I will present simulation methods I developed to simulate blood-involved phenomena at different scales. Firstly, I will show a pure Eulerian method dedicated to the simulation of individual or suspension of blood cells. This framework uses the level set method to capture efficiently the mechanical behavior of each cell individually as well as the interaction between the cells and the fluid.

In a second part, I will present a numerical framework able to perform the direct numerical simulation of mass transfer from vascular network to the tissues, as well as the upscaling of such systems. The upscaling technique will use the two-equations homogenization technique and will be compared to direct simulations. I will show how to perform such simulations on anatomically accurate geometries.