LadHyX Seminar – November 16th, 1:30 pm

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Computational Biomechanics: From Thrombosis to Aortic Hemodynamics and Nuclear Deformation

Computational models can help explain how local mechanical conditions shape biological responses, from platelet aggregation in disturbed blood flow to nuclear deformation on microstructured surfaces. This presentation brings together three studies that combine numerical modeling with experimental or clinical observations to investigate thrombus formation, changes in aortic hemodynamics after endovascular repair, and the deformation of cell nuclei on microgrooved substrates. Thrombosis, the process of pathological blood clot formation, constitutes one of the leading causes of death worldwide. Thrombosis is governed by both biochemical and mechanical considerations. Experimental evidence based on both in vivo and in vitro data suggests that beyond the effect of shear stress alone, local spatial changes in blood shear rate, i.e. spatial shear gradients, play a critical role in controlling the process of platelet aggregation. In light of the above, understanding and predicting thrombus onset and growth in conditions of blood shear changes is of major interest. This is the case for various pathological conditions including stenoses, aneurysms as well as some postoperative scenarios and endovascular device implantation. In this perspective, the availability of a computational model capable of reliably predicting thrombus formation in the presence of flow alterations is crucial.

The goal of this work was to develop a predictive computational model of thrombus formation that incorporates for the first time, in addition to the biochemical aspects, the effects of shear gradients. The model accounts for both chemically- and mechanically-induced platelet activation and aggregation, fibrin generation, along with the effect of thrombus growth on the local fluid dynamics and how this feeds back into the process of thrombogenesis. The second study investigates how thoracic endovascular aortic repair (TEVAR) alters blood flow in the aortic arch, basing on a cohort of patients of which 4D MRI conditions were collected. The comparison seems to suggest that the TEVAR has a beneficial effect on the aortic arch hemodynamics. The third study uses a two-dimensional fluid–structure interaction model to examine how microgrooved substrates deform endothelial cell nuclei. The nuclear envelope is represented as a hyperelastic solid, the chromatin as a highly viscous fluid, and the microgrooves as rigid structures. The model suggests that mechanical loading and geometric confinement contribute to the deformation.