Numerical Analysis and Scientific Computing Seminar

A computational model of drug delivery through microcirculation to compare different tumor treatment options

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Abstract: Starting from the fundamental laws of filtration and transport in biological tissues, we develop a mathematical model able to capture the interplay between blood perfusion, fluid exchange with the interstitial volume, mass transport in the capillary bed, through the capillary walls and into the surrounding tissue. These phenomena are accounted at the microscale level, where the capillary bed and the interstitial volume are viewed as two separate regions. The capillary bed is described as a network of vessels carrying blood flow. We complement the model with a state of art numerical solver, based on the finite element method. The numerical scheme is based on the idea to represent the capillary bed as a network of one-dimensional channels that acts as a concentrated source of flow immersed into the interstitial volume, because of the natural leakage of capillaries. As a result, it can be classified as an embedded multiscale method. We apply the model to study drug delivery to tumors. Owing to its general foundations, the model can be adapted to describe and compare various treatment options. In particular, we consider drug delivery from bolus injection and from nanoparticles, which are in turn injected into the blood stream. The computational approach is prone to perform a systematic quantification of the treatment performance, enabling the analysis of interstitial drug concentration levels, drug metabolization rates, cell surviving fractions and the corresponding timecourses. Our study suggests that for the treatment based on bolus injection, the drug dose is not optimally delivered to the tumor interstitial volume. Using nanoparticles as intermediate drug carriers overrides the shortcomings of the previous delivery approach. Being directly derived from the fundamental laws of flow and transport, the model relies on general foundations and it is prone to be extended in different directions. On one hand, we are planning to combine it with a poroelastic description of the interstitial tissue, in order to capture the interplay of mechanical deformations and transport phenomena. On the other hand, the model may be adapted in future to study different types of cancer, provided that suitable metrics are available to quantify the transport properties of a specific tumor mass.

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Refreshments will be provided

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