Simulation of water transport in the skin interstitial space

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Water, oxygen, nutrients and metabolites are transported to and from cells across the capillary wall and through the interstitial spaces of tissues. The interstitial space is a heterogeneous porous structure that is composed of two main phases: “solid” collagen fibers primarily supplying mechanical support of the tissue, and a fluid-rich gel providing aqueous “channels” for transport of water and solutes. Given the complexity of the interstitial geometry and the inherent difficulties in identifying its functional in vivo structure, very little is actually known about the local mechanisms mediating interstitial transport. Many bulk transport characteristics can be measured and there are numerous modeling approaches in the classical physiology literature. However, no adequate model is yet available.

In this project, we start with a simple geometrical model for the interstitial space considered as a pack of randomly oriented cylinders representing collagen fibers. This model of a porous medium had been studied in different contexts, in particular, in material sciences. Here we will adapt it to investigate the consequences of structural changes associated with acute injury, wound healing and chronic inflammatory and degenerative processes, by modifying key geometrical parameters. As the starting point, diffusion in a pack of cylindrical fibers will be modeled by Monte Carlo techniques (fast geometry-adapted random walks), which are flexible and easily adaptable to various geometrical models. A good theoretical knowledge and practical skills in computer sciences, numerical methods, applied mathematics and programming are welcomed. This numerical investigation should reveal how packing geometric parameters (porosity, diameter of cylinders, polydispersity, spatial distribution, etc) can affect various transport characteristics, in particular, time-dependent concentration.

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