

MODELING OF FLUID AND SOLUTE TRANSPORT IN HETEROGENEOUS POROUS MEDIUM: THE ROLE OF EXTRACELLULAR MATRIX PROPERTIES IN PERITONEAL THERAPIES

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ABSTRACT

In peritoneal therapies, application of high hydrostatic and/or osmotic pressure gradients, together with concentration differences, drive the transport of fluid and solutes between the peritoneal cavity and blood through the adjacent tissue. The interstitial matrix of the peritoneal tissue can be regarded as a porous medium through which fluid and solutes are transported, enabling the delivery of drugs and the removal of toxins and excess water from the body. Therapy-induced fluid transport alters local tissue hydration and interstitial pressure, which in turn modify the local transport properties of the extracellular matrix. These properties therefore vary both spatially and temporally and depend on the local hydration state affecting fluid and solute transport and, consequently, the effectiveness of the therapy.

A mathematical model with spatially distributed transport parameters can be formulated based on experimental and clinical observations. The model combines fluid-volume and solute-mass balances across the peritoneal tissue with the local transport properties described as functions of tissue hydration. This formulation leads to a system of highly nonlinear partial differential equations describing fluid and solute transport within the interstitium. In addition, the temporal evolution of volume and solute concentrations at the boundary are described by a system of ordinary differential equations. The ODEs define the boundary conditions for the tissue transport problem, while simultaneously depending on the fluid and solute fluxes through the peritoneal tissue.

The mathematical framework provides a tool for investigating how spatial and temporal heterogeneity induced by changes in tissue hydration influences transport dynamics and treatment efficiency. The role of hydration-dependent extracellular matrix properties and their spatiotemporal heterogeneity will be illustrated by numerical simulations based on two applications: peritoneal dialysis and intraperitoneal chemotherapy.