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Modeling of osmotic transport during peritoneal dialysis

Peritoneal dialysis is a medical treatment of patients with end stage renal disease aimed at removal of waste products such as urea or creatinine as well as the excess water from patient's organism. In peritoneal dialysis, hypertonic fluid is infused into the peritoneal cavity. As a result, the intraperitoneal pressure and osmotic gradient increase, causing bidirectional fluid and solute exchange between peritoneal cavity and blood through the tissue layers that surround peritoneal cavity. The fluid removal by ultrafiltered water (due to osmotic force) into the peritoneal cavity, is decreased by the water absorption in the opposite direction, and depends on the local properties of transport barriers. The clinically used phenomenological model such as a membrane model or the three-pore model, allows for the evaluation of diffusive and convective peritoneal transport parameters. However, due to their phenomenological character, they can not be used for the identification of the physiological causes behind observed changes in the values of transport parameters during peritoneal dialysis. The distributed approach is based on the local geometry of the capillary bed and lymphatics distributed within the tissue that surrounds peritoneal cavity.

Based on a distributed model of peritoneal transport, a mathematical theory was proposed to explain how the osmotic agent in the peritoneal dialysis solution that penetrates tissue induces osmotically driven flux out of the tissue [1]. Validation of the model with the available clinical and experimental data showed its good accuracy [1]. The relationships between phenomenological effective transport parameters (hydraulic permeability, reflection coefficient) and the respective specific local transport parameters for the tissue and the capillary wall were separately derived [1]. An extension of the model for the changes in the peritoneal fluid components and their connection with the changes in the tissue described by the distributed model were proposed and positively validated with available data [2]. Numerical simulations of the model gave insight not only into the clinically observable changes in the peritoneal fluid, but also in the corresponding changes in the tissue that occur during the treatment and cannot be directly observed [2].

References

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