THE EFFECT OF ELECTRIC CHARGE ON PROTEIN TRANSPORT DURING PERITONEAL DIALYSIS AS DESCRIBED BY THE THREE PORE MODEL

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OBJECTIVES

To incorporate the effect of negative charge of proteins into the three pore model and investigate influence of that modification on the transport parameters of the peritoneal barrier.

Table 1. Sums of squared relative errors.

Solute	Standard 3-pore model	Modified 3-pore model
Urea	0.025 ± 0.0235	0.25 ± 0.0236
Glucose	0.0455 ± 0.1167	0.0455 ± 0.1167
Sodium	$10^{-4} \pm 2x10^{-4}$	$10^{-4} \pm 2x10^{-4}$
Creatinine	0.0146 ± 0.0135	0.0146 ± 0.0135
Phosphate	0.0396 ± 0.0412	0.0396 ± 0.0413
IgM	0.0115 ± 0.0144	0.0116 ± 0.0144
Albumin	**2.81 ± 3.69***	**0.38 ± 0.57**

* different between model with p-value < 0.05

Table 2. Estimated transport parameters.

Parameter	Standard 3-pore model	Modified 3-pore model
LpS [mL/min/mmHg]	0.050 ± 0.024	0.050 ± 0.024
PA	1.05 ± 0.66	1.04 ± 0.65
PS_G	8.4 ± 2.6	8.4 ± 2.6
PS_{Na}	5.2 ± 2.9	5.2 ± 2.9
PS_U	18.1 ± 4.2	18.1 ± 4.2
PS_{Cr}	9.0 ± 3.1	9.0 ± 3.1
PS_P	10.6 ± 3.6	10.6 ± 3.6
PS_A	0.017 ± 0.018	0.018 ± 0.023
α_u	0.045 ± 0.037	0.044 ± 0.036
α_s	0.820 ± 0.100	0.816 ± 0.100
α_l	0.135 ± 0.078	0.139 ± 0.079

[a] LpS - hydraulic permeability; PA - peritoneal absorption rate; α_u, α_s, α_l - fractional contribution of ultrasmall, small and large pores to LpS; PS_G, PS_{Na}, PS_U, PS_{Cr}, PS_P, PS_A - diffusive mass transport coefficients for glucose (G), sodium (Na), urea (U), creatinine (Cr), phosphate (P), and albumin (A)

METHODS

Patient data. Sequential peritoneal equilibration test (sPET, Galach et al, 2013) was performed in 32 patients on continuous ambulatory peritoneal dialysis (glucose 2.27% for 4 h and glucose 3.86%, for 1 h). The concentrations of urea, creatinine, glucose, sodium, phosphate, albumin and IgM were measured in dialysis fluid at the beginning, in the middle and at the end of each peritoneal dwell.

Two transport models. Standard (s3p) and modified (m3p) three-pore model. The negative charge of proteins can be taken into account in mathematical models of transport processes by the change in the radius of macromolecules and transport pores by a fraction of Debye length characteristic for the ionic strength, as shown for the glomerular membrane by Öberg & Rippe (Am J Physiol, 2013). Hence, in the m3p model the radiuses of proteins were increased by 1.5 A, and the pore diameters were decreased by 1.5 A for protein transport.

Estimation procedure. We estimated hydraulic permeability (LpS), contribution of specific type of pores to LpS (aU, aS, and aL for ultrasmall, small and large pores, respectively), peritoneal fluid absorption (PFA) and diffusive mass transport parameters for small solutes (PS). The parameters were estimated without albumin taken into account and then albumin concentrations in dialysate were predicted (with adjusted albumin diffusivity) and compared to the measured values.

RESULTS

Table 1:
❖ Both considered 3p models yielded equally precise description of the transport of fluid, small solutes, and IgM.
❖ The modified 3-pore model provided a better description of albumin concentration in dialysis fluid.

Table 2:
❖ The estimated transport parameters were similar for both models.

Figure 1:
❖ The s3p model substantially overestimated the albumin transport during dwells with glucose 3.86%.
❖ The m3p model mildly underestimated albumin transport during the dwells with glucose 2.27% fluid.
❖ The predicted profiles for albumin and IgM tended to equilibrate slowly with dwell time in contrast to the straight line profiles measured for both dialysis fluids.

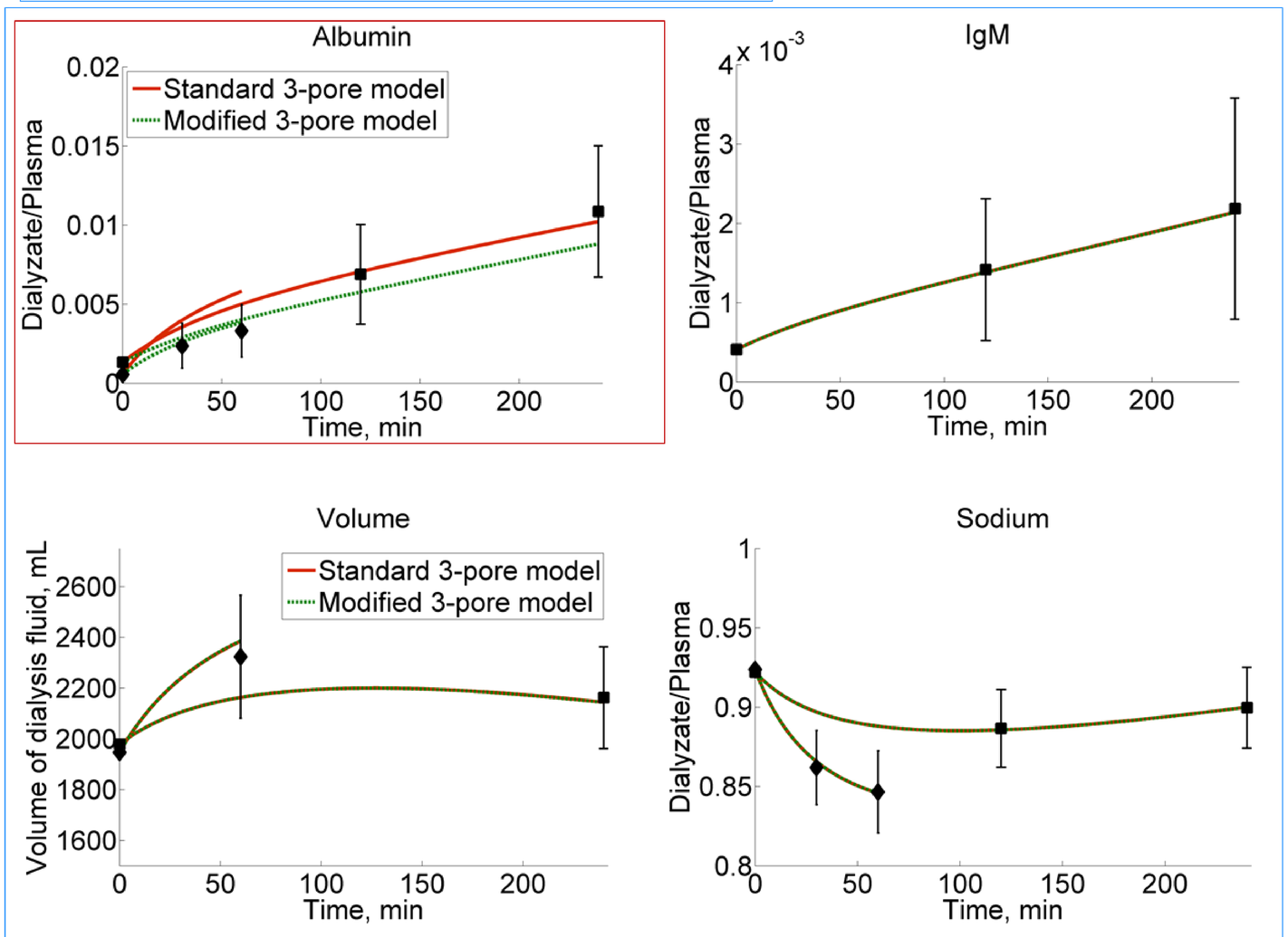

Figure 1. The average model predicted curves and corresponding experimental data (mean ± SD).

CONCLUSIONS

The 3p model with the electric charge of proteins taken into account was able to predict albumin transport with higher accuracy than the standard version of the model. However, both models had considerably higher errors for albumin concentrations in dialysis fluids than those for fluid and other solutes. The predicted equilibration of protein profiles demonstrated a problem in the correct description of the relationship between diffusive and convective transport of albumin by both models. No important difference in the estimated values of parameters for the two models was found.

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