Dynamic Changes of the Total Pore Area Available for Peritoneal Exchange in Children

MICHEL FISCHBACH* and BÖRJE HARALDSSON†
*Nephrology Dialysis Transplantation Children’s Unit, Strasbourg, France; and †Departments of Nephrology and Physiology, Göteborg University, Gothenburg, Sweden.

Abstract. The most important of the parameters that describe exchange across the peritoneal membrane is the total pore area over diffusion distance ($A_0/\Delta x$). It determines the rate of diffusion and mainly seems to reflect the number of capillaries available for exchange. In the present study, a simplified three-pore analysis was used to estimate $A_0/\Delta x$ from peritoneal equilibration tests. Two groups of children (mean age, 9.5 yr) who were on chronic peritoneal dialysis underwent studies with peritoneal equilibration tests. In the first group of children, three levels of fill volumes were used in each patient. In the second group of patients, the effects of posture and dwell time were analyzed from four consecutive peritoneal dialysis samples obtained after 15, 30, 60, and 90 min. As the fill volume was raised from 800 to 1400 ml/m² BSA, the steady-state $A_0/\Delta x$ increased significantly by 21%, i.e., from 19,900 ± 1200 to 24,000 ± 1450 cm²/cm per 1.73 m² ($n=8$). A further increase to 2000 ml/m² did not result in any change of $A_0/\Delta x$. Moreover, steady-state $A_0/\Delta x$ fell significantly when the patients were standing, 21,900 ± 1400 compared with 29,400 ± 1330 cm²/cm per 1.73m² ($n=6$) obtained in the supine position. There was a transient (<30 min) increase in $A_0/\Delta x$ initially during the dwell, probably reflecting vasodilation and recruitment of capillaries. It is concluded that factors such as the intraperitoneal fill volume, posture, and dwell time all dynamically affect the total pore area available for exchange.

Peritoneal dialysis (PD) has become an increasingly popular therapy modality, particularly for children. There are many differences between hemodialysis and PD, one being that the latter uses a biologic membrane instead of an artificial dialyzer. Therefore, it is even more important to measure and individualize the dose of dialysis during PD (1). In the past decade, our knowledge of the transport processes across the peritoneal membrane has expanded considerably. In particular, the three-pore model has been most successful in predicting the transperitoneal exchange of fluid and solutes. According to this theoretical model introduced by Rippe et al. (2,3), the peritoneal membrane contains three populations of functional pores: the water-exclusive aquaporins (1, 3, and 4) (4), the small-pore pathways (radius, 4.7 nm), and the large-pore pathways (radius, 25 nm). The frequencies of the pores are inversely related to their pore sizes. Thus, there are approximately $10^6$ aquaporins and $10^4$ small pores on every large pore. With the three-pore model, it is possible to predict the exchange of solutes depending on their molecular size and the osmotic effect of various substances (5). Indeed, the model seems to be universal for microvascular beds in general (6). These physiologic concepts also have been used to estimate the PD capacities (PDC) of individual patients (7).

Three basic PDC parameters characterize the peritoneal membrane. First and most important is the “area parameter,” or the total pore area over diffusion distance ($A_0/\Delta x$), which is a fundamental physiologic expression. $A_0/\Delta x$ determines the mass transfer area coefficient (MTAC) for any hydrophilic solute. Note that $A_0/\Delta x$ is not unique for the three-pore model but rather is a fundamental physicochemical parameter for transport across porous membranes. Second, the “absorption” parameter ($J_{v_AR}$) denotes the final reabsorption rate of fluid from the abdominal cavity to blood when the glucose gradient has dissipated. This lumped parameter includes lymph flow (L) and the “Starling forces” across the capillary wall, i.e., $J_{v_AR} = \text{LpS} \cdot [\Delta P - \sigma \Delta \pi] + \text{L}$, where $\Delta P$ and $\Delta \pi$ are the net hydrostatic and colloid osmotic pressure gradients, respectively, and $\sigma$ is the average reflection coefficient for proteins. Third, the “plasma loss” parameter ($J_{v_L}$) equals the flow of plasma-like fluid from blood to the abdominal cavity through the large pores. The reflection coefficient for proteins across the large pores, $\sigma_L$, is close to 0, so $J_{v_L} \approx \text{LpS} \cdot f_L \cdot \Delta P$ (see reference 7 for details).

The complete analysis of the three-pore parameters requires a rigorous measuring protocol that includes information of dwell times, intraperitoneal volumes, and concentrations of various solutes from several PD exchanges. However, the fundamental area parameter, $A_0/\Delta x$, can be estimated from the dialysate over plasma concentration ratios (D/P) derived from individual peritoneal equilibration tests (PET). This is made possible by assuming the other three-pore parameters to be constant. Hereby, we apply the complete three-pore analysis to the PET data, allowing for both diffusive and convective transport of solutes through the small- and large-pore pathways.
In a previous study (8), the effects of posture were evaluated in terms of PET (9) and intraperitoneal pressures. Both parameters were affected by posture as well as by fill volume (FV) (10). Many investigators interpret changes in PET in terms of “transport” or “peritoneal permeability” (8,11). Albeit useful from a practical point of view, these terms do not, however, give us any information of the underlying mechanisms in the peritoneal membrane. PET and \( A_0/\Delta x \) from PDG have been compared against an independent technique, namely the uptake of iohexol from the abdominal cavity (12). The results showed that \( A_0/\Delta x \) was superior to PET in predicting the plasma appearance of iohexol. Hence, \( A_0/\Delta x \) gives a better description of the peritoneal function than PET (12). Indeed, several factors may affect the D/P ratios and, hence, PET: (1) the area available for exchange (\( A_0/\Delta x \)), (2) the intraperitoneal volume, (3) the rate of “ultrafiltration,” (4) the lymph flow, (5) the pore sizes, and (6) the relative number of pores.

In the present study, we used a simplified three-pore analysis (7) to estimate the area parameter, \( A_0/\Delta x \), from PET data from children who were on PD. We studied the dynamic effects on \( A_0/\Delta x \) of using different FV and different body positions and the influence of dwell time. Our results show that such analyses give valuable insights into the peritoneal function of individual patients.

Materials and Methods

Study Groups

Experiments were performed on two groups of patients. In group A, the effect of FV was studied in eight children with a mean age of 9 yr and 6 mo (range, 2 to 16 yr). In group B, we studied six children with a mean age of 9 yr and 5 mo (range, 5 to 16 yr) in supine and upright positions. Part of the patient material has been published previously (8), but the data were completely reanalyzed.

Variables

The concentrations of urea, creatinine (after due correction for the interference of glucose), phosphate, protein, and glucose were analyzed in plasma (P) and dialysate (D). D/P concentration ratios for the solutes were computed, except for glucose, where the initial concentration (D0) was calculated and D/D0 values were estimated.

Study Protocol

Effect of Fill Volume. Three levels of peritoneal FV were used: 800, 1400, and 2000 ml/m². The dialysate concentrations were analyzed after 60 min in a supine position.

Effect of Posture. The effect of posture was estimated by measuring the D/P and D/D0 values after 60 min in a supine or standing position. The FV was 1000 ml/m² in this group of patients.

Effect of Time. The three-pore model analysis was performed on four consecutive PD samples obtained after dwell times of 15, 30, 60, and 90 min with FV of 1000 ml/m² on the same patients as in B.

Calculations

The fundamental significance of the area parameter (\( A_0/\Delta x \)) is evident from the following equation:

\[
MTAC_X = D_X \cdot \left( \frac{A_0}{\Delta x} \right) \cdot \frac{A_0}{\Delta x}
\]

(1)

MTAC\(_X\) is the mass transfer area coefficient for a solute \( X \). \( D_X \) is the free diffusion constant, and \( (A_0/\Delta x)_X \) is the pore restriction factor for the solute. Moreover, \( D_X \) and \( (A_0/\Delta x)_X \) are computed easily from the Stokes-Einstein radius of the solute (see reference 7). Thus, once \( A_0/\Delta x \) is known, the diffusive transport can be calculated for any solute of known size, thus allowing for predictions of the actual net transport of the solute.

Initially during a PD dwell, there seems to be a vasodilation and recruitment of capillaries (13). This was recognized early in the PDC software (7), and an empirical equation was derived previously (14) to calculate the steady-state \( A_0/\Delta x \):

\[
\frac{A_0}{\Delta x}(t) = \frac{A_0}{\Delta x} \cdot (1 + e^{-0.08t})
\]

(2)

Where \( A_0/\Delta x(t) \) is the area parameter at a given time calculated from the steady-state \( A_0/\Delta x \). According to equation 2, already after 30 min \( A_0/\Delta x(t) \) is close to the steady-state value (+9%), despite an initial 100% increase.

So far, the analysis has focused on diffusive transport and has not involved any specific three-pore model parameter. During PD, however, there are convective fluxes through the pore pathways. Thus, at any given time \( t \), the fluid flux through each pore will equal:

\[
J_{V_j} = LpS \cdot f_j \cdot [\Delta P(t) - \sigma_{j,prot} \cdot \Delta \pi_{prot}(t) - \sum \sigma_{j,i} \cdot \Delta \pi(i)]
\]

(3)

where \( LpS \) is the ultrafiltration coefficient and \( f_j \) is the fraction of \( LpS \) accounted for by the particular pore pathway \( j \). Thus, \( f \) is close to 1% for the aquaporins, 5% for the large pores, and 94% for the small-pore pathway. \( \Delta P(t) \) and \( \Delta \pi_{prot}(t) \) are the hydrostatic and colloid osmotic pressure gradients at time \( t \), values that are almost constant. The reflection coefficient for proteins, \( \sigma_{j,prot} \), will determine how effective the colloid osmotic pressure is across that particular pore (7). The third term in the brackets, \( \sum \sigma_{j,i} \cdot \Delta \pi(i) \), is the sum of all effective crystalloid osmotic gradients. For aquaporins, all \( \sigma \) are close to unity, whereas they are close to 0 for the large pores. Finally, the clearances for a solute (CL\(_x\)) through the small and the large pores are calculated for from the individual pore MTAC, \( J_{V} \) and \( \sigma \), using the following nonlinear flux equation (7):

\[
CL_X(t) = \frac{Jv(t) \cdot \left( 1 - \sigma_X \right)^2 \left( 1 - D/P(t) \cdot e^{-Pe(t)} \right)}{1 - e^{-Pe(t)}}
\]

(4)

where \( D/P \) is the dialysate over plasma concentration ratio at time \( t \) and \( Pe(t) \) is the Peclet number at time \( t \), which is given by the following equation:

\[
Pe(t) = \frac{Jv(t) \cdot \left( 1 - \sigma_X \right)}{MTAC_X}
\]

(5)

More details of the equations used in the modified three-pore model and the properties of the solutes are described elsewhere (6,7,14). Phosphate is of a particular interest, not only from a clinical point of view but also in terms of modeling. Approximately 30% of plasma phosphate is bound to proteins. Furthermore, phosphate is a buffer with a pK of 6.8, suggesting that 80% is present in the form of HPO\(_4^{2-}\) and the rest as H\(_2\)PO\(_4^-\) at physiologic pH. The two phosphate ions have a similar diffusion constant (1.16 \( 10^{-5} \) cm\(^2\) s\(^{-1}\)), hence Stokes-Einstein radii (0.28 nm). No correction seems to be required for the pH of the PD fluid, because the intraperitoneal pH rapidly will approach the physiologic levels. However, for shorter dwell times, such as during high-volume ambulatory PD, the buffering effect of phosphate may affect transport.
To use the PET values as data input for the three-pore analysis, we
developed new computer software. The effects of dialysis were sim-
ulated during the first 60 min with 1-min increments. The parameters
of the three-pore model are given in Table 1. Only $A_0 / D_x$ was allowed
to change; the other parameters were constant. The hydraulic conduc-
tance changed in proportion to $A_0 / D_x$. In each patient, five solutes
were used to compute $A_0 / D_x$, namely urea, creatinine, phosphate,
protein, and glucose. The best fit between measured and modeled $D/P$
and $D/D_0$ concentration ratios were obtained by numeric integration
using the values in Table 1 as start values in the iterative process.

**Statistical Analyses**

Results are given as mean ± SEM. A $t$-test paired design was used
to analyze the effects of posture and FV. $P < 0.05$ was considered to
be statistically significant.

**Results**

Only changes of $A_0 / D_x$ predicted the biologic data. Thus,
changing any of the other parameters (the final reabsorption
rate, the large pore fluid flux, the small- and/or the large-pore
radius, the hydrostatic pressure gradients, the number of aqua-
porins, or the ultrafiltration coefficient) resulted in less preci-
sion in the predictions of the $D/P$ concentration ratios. In
addition, none of these parameters was able to describe the
effects of FV and/or position. Therefore, this article focuses on
the changes of $A_0 / D_x$.

**Effects of Peritoneal FV**

The steady-state total pore area over diffusion distance,
$A_0 / D_x$, was $19,900 ± 1200$ cm$^2$ cm$^{-1}$ (1.73 m$^2$ body surface
area)$^{-1}$ for a FV of 800 ml/m$^2$ (789 ± 22 ml/m$^2$). For an FV
of 1400 ml/m$^2$ (1360 ± 22 ml/m$^2$), the $A_0 / D_x$ was $24,000 ±
1450$ cm$^2$/cm per 1.73m$^2$. The 21% increase was highly sig-
nificant ($P < 0.001; n = 8$). Increasing the FV further to 2000
ml/m$^2$ (1950 ± 33 ml/m$^2$) did not induce any significant
change of $A_0 / D_x$ being $24,500 ± 1700$ cm$^2$/cm per 1.73m$^2$.
Figure 1 illustrates the results.

To ensure that the relationship in Figure 1 was not caused by
the normalization procedure, the uncorrected $A_0 / D_x$ (in cm$^2$/
cm) of the individual patients were plotted against the actual
FV (in ml; Figure 2).

These estimates of $A_0 / D_x$ were based on three-pore analysis
of the 60-min $D/P$ concentration ratios for urea, creatinine,
phosphate, and protein as well as the $D/D_0$ concentration ratio
for glucose. To visualize the reliability of these calculations,
we used the computed $A_0 / D_x$ value to simulate $D/P$ and $D/D_0$
ratios for the five solutes. As shown in Figure 3, the modeled
$D/P$ or $D/D_0$ values were in close agreement with the measured
data. Thus, the linear regression of Figure 3 is $y = 0.94x +
0.014$, $r^2 = 0.974$. As previously mentioned, except for $A_0 / D_x$,
none of the parameters in Table 1 was able to describe the
effects of changing FV. We used equation 2 in these calcula-
tions to estimate the steady-state $A_0 / D_x$ but similar results with
the non–steady state $A_0 / D_x$.

**Effects of Posture**

In the supine position the steady-state total pore area over
diffusion distance, $A_0 / D_x$, was $29,400 ± 1330$ cm$^2$ /cm per

**Table 1. Parameters of the three-pore model**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>“Normal” Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted area per cm diffusion distance</td>
<td>$A_0 / D_x$</td>
<td>23 000</td>
<td>cm$^2$/cm/1.73m$^2$</td>
</tr>
<tr>
<td>Small-pore radius</td>
<td>$r_s$</td>
<td>4.7</td>
<td>nm</td>
</tr>
<tr>
<td>Large-pore radius</td>
<td>$r_L$</td>
<td>25</td>
<td>nm</td>
</tr>
<tr>
<td>UF coefficient</td>
<td>$LpS$</td>
<td>0.07</td>
<td>ml/min/mmHg/1.73m$^2$</td>
</tr>
<tr>
<td>Aquaporin fraction of the UF coefficient</td>
<td>$f_c$</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Large-pore fraction of the UF coefficient</td>
<td>$f_L$</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Small-pore fraction of the UF coefficient</td>
<td>$f_s$</td>
<td>0.94</td>
<td></td>
</tr>
<tr>
<td>Hydrostatic pressure gradient</td>
<td>$\Delta P$</td>
<td>14</td>
<td>mmHg</td>
</tr>
<tr>
<td>Plasma oncotic pressure</td>
<td>$\pi_p$</td>
<td>27</td>
<td>mmHg</td>
</tr>
<tr>
<td>Final reabsorption rate</td>
<td>$J_{V AR}$</td>
<td>1.2</td>
<td>ml/min/1.73m$^2$</td>
</tr>
<tr>
<td>Plasma loss through large pores</td>
<td>$J_{V L}$</td>
<td>0.08</td>
<td>ml/min/1.73m$^2$</td>
</tr>
</tbody>
</table>

* UF, ultrafiltration.
1.73m² (n = 6). When the patients were standing, A₀/Δx fell significantly to 21,900 ± 1400 cm²/cm per 1.73m², i.e., to 74 ± 2% of the supine values (P < 0.001; n = 6; see Figure 4). The calculated D/P or D/D₀ concentration ratios showed a good agreement similar to that seen in Figure 3. Similar results were obtained with the non–steady-state A₀/Δx values. For no obvious reason, this group of children had a higher peritoneal diffusion capacity than those in group A (with similar FV) with respect both to PET and to A₀/Δx.

**Effects of Dwell Time**

In the first analysis of the effect of dwell time, the non–steady-state A₀/Δx were used, i.e., the initial vasodilation described by equation 2 was not used. Under these conditions, the A₀/Δx fell with dwell time and was for the supine position 117%, 133%, and 102% of the 90-min values at 15, 30, and 60 min, respectively. In the upright position, the non–steady-state A₀/Δx values were 113% at 15 min, 132% at 30 min, and 105% at 60 min compared with the 90-min values. The difference between the 15- and 30-min values was significant, as was the fall of A₀/Δx with dwell time. Figure 5A illustrates the effects of dwell time on the non–steady state A₀/Δx.

Including the initial vasodilation and capillary recruitment (equation 2) in the analysis to estimate the steady-state A₀/Δx gave more stable values as seen in Figure 5B. Note that the 15-min values are still lower than the 30-min values (within 10%) but there is no apparent effect of dwell time. Thus, in the supine position, steady-state A₀/Δx was 28,400 ± 2320 cm²/cm per 1.73m² at 15 min, 35,000 ± 2510 cm²/cm per 1.73m² at 30 min, 30,700 ± 1910 cm²/cm per 1.73m² at 60 min, and 31,700 ± 2920 cm²/cm per 1.73m² at 90 min. In the upright position, the corresponding steady-state A₀/Δx values were 20,100 ± 1710, 25,300 ± 2210, 23,000 ± 1870, and 23,200 ± 1840 cm²/cm per 1.73m² for 15, 30, 60, and 90 min, respectively. The differences between the two positions were highly significant for all dwell times.

**Discussion**

The main finding in the present study is that the area available for exchange is dependent on FV and posture in children who are treated with PD. These dynamic alterations of the area parameter have important clinical implications and may provide help in understanding peritoneal exchange. Thus, the total pore area per cm diffusion distance, A₀/Δx, increased by 21% as the FV increased from 800 to 1400 ml/m² BSA (see Figure 1). The pattern was almost identical in all patients studied (see Figure 2). Moreover, the modified three-pore analysis had a very high predictive power as evident from Figure 3. Note also that increasing the FV to 2000 ml/m² did not result in any further elevation of the A₀/Δx (see Figure 1).

In a separate group of children, we found that A₀/Δx in the supine position was 35% higher than that during standing.
Finally, we found evidence for an initial dynamic increase of $A_0/\Delta x$ during a PD dwell as described previously for adults (7,14) and for rats (13).

What is the physiology behind the term total pore area over diffusion distance, $A_0/\Delta x$? As can be seen from equation 1, $A_0/\Delta x$ will determine the diffusion capacities (MTAC) for all solutes. $A_0/\Delta x$ has two inseparable components, namely the total pore area ($A_0$) and the average diffusion distance between blood and dialysate ($\Delta x$). More specific, $A_0$ is the product of the number of perfused capillaries in contact with the dialysate, the number of pores per capillary, and the area of each of these pores. $A_0/\Delta x$ is crucial for the exchange in all microvascular beds (6). Thus, each capillary contains a large number of functional small pores, but the size of these pores is remarkably constant (6). The number of small pores per capillary probably also is a static variable (15), as is $\Delta x$. Studies in other organs show that $A_0/\Delta x$ is a highly dynamic parameter related to the number of exchange vessels that are being perfused at a given time (15). Therefore, the peritoneal $A_0/\Delta x$ most likely is controlled by the number of perfused capillaries that are in contact with the PD fluid. Thus, during standing and/or with low FV, fewer capillaries are in contact with the PD fluid. Note that $A_0/\Delta x$ does not represent the total peritoneal membrane surface. The latter, however, can be estimated by a morphometric technique (16), but $A_0/\Delta x$ is a more dynamic parameter related to microcirculation.

One might ask whether $A_0/\Delta x$ really is better than the information that we get from a PET. This was investigated in a recent study in which $A_0/\Delta x$ from a PDC test was compared with PET data from the same patient (12). The plasma appearance rate of intraperitoneal iohexol ($k_{\text{pari}}$) was used as an independent estimate of peritoneal function and was found to correlate well with $A_0/\Delta x$, whereas the correlation of $k_{\text{pari}}$ and PET was considerably weaker. Thus, the authors concluded that $A_0/\Delta x$ is superior to PET as an indicator of peritoneal function (12).

One might argue that we have neglected the convective fluxes in the present analysis. That is not the case, however, because both diffusion and convection were included in the present three-pore analysis. Indeed, convection predominates for solutes of large molecular size. For the sake of simplicity, the other parameters of the three-pore model were constant (see Table 1).

A relationship between peritoneal exchange area and FV was noted in a previous study on adults when the MTAC for glucose, urea, and creatinine were normalized to 2-L dwells and plotted versus “true dialysis volume” (17). In that study, the authors used regression techniques and indirect reasoning to differentiate between effects on permeability from those on peritoneal membrane surface area. Changes in MTAC were attributed to the latter. Moreover, they found that a parabolic function gave the best fit and suggested that MTAC reach a peak value at a certain FV. Further increases in FV were expected to result in a decline of MTAC. Hence, the authors concluded that there is an “ideal” FV for each patient at which MTAC reaches a maximum. Contrasting results were obtained in a study on rats (18) in which the FV did not affect the exchange of small solutes to the extent reported from the studies in humans. Our analysis supports the view of Kesha-viah et al. (17) that the FV do indeed affect the area available for exchange. The $A_0/\Delta x$ does not seem to decline at higher FV, however, but rather seems to reach a plateau. Note that the largest FV in this study would be equivalent to a 3.5-L exchange in adults (BSA, 1.73m²). For children, the “maximum” area available for exchange is obtained at FV of 1400 ml/m² (2.4 L in an adult; BSA, 1.73 m²). Again, our observations are in agreement with the findings in the study of iohexol uptake from the abdominal cavity (12). Thus, in that study on adult patients, $A_0/\Delta x$ was close to 19,000 cm²/cm at an FV of 1000 ml/m² and fell to 5000 cm²/cm per 1.73m² as the FV was reduced to 250 ml/m² BSA (12).

The effect of posture on the peritoneal exchange has been studied in children (8) and adults (11,19). In these studies, the authors noted a fall in MTAC in the standing position compared with the supine situation. Again, this could be due to changes in the “intrinsic” permeability (11) or to alterations in the area available for exchange. Applying the modified three-pore model to the data by Fischbach et al. (8) clearly demon-
strated that the area parameter (A₀/Δx) in the upright position was 74% of that estimated when the patient was lying down.

The MTAC for small solutes initially are higher during a PD dwell and decrease gradually within the first hour. In a recent study on rats, this was found to be due to vasodilation rather than interstitial discharge (13). Such effects are encountered in the present three-pore model by the empirical equation (equation 2) (7), giving steady-state A₀/Δx.

The present three-pore analysis is based on D/P (and D/D₀) concentration ratios for several solutes. The analysis was simplified, however, by assuming the other PDC parameters (7) of Table 1 to be constant. This assumption was necessary because a more complete determination of the three-pore parameters would require more laborious collection of data, i.e., the PDC protocol (7). However, the errors with respect to the absolute values for A₀/Δx were found to be small, as was evident after selective alteration of the other parameters in Table 1. For example, altering the ultrafiltration coefficient with a factor of 2 affects A₀/Δx less than 1%. The solutes measured represent small solutes, and the discriminative power for detecting changes of the pore radii therefore is somewhat limited. However, changes in the pore radii or the relative number of pores did not result in acceptable simulations of the biologic data, whereas changes in A₀/Δx did.

In conclusion, the most important physiologic parameter that controls peritoneal exchange, A₀/Δx, can be estimated adequately from PET data. There was a good fit between the D/P ratios estimated from children and those calculated by the three-pore model in its present form. The three-pore analysis is a theory based on our current understanding of capillary physiology that may facilitate our understanding of the clinical situations during PD. Thus, the “area” (A₀/Δx) increases with FV and when the patient goes from standing to a supine position. The results underscore the dynamic nature of the area available for peritoneal exchange. Finally, an FV of approximately 1400 ml/m² seems to be optimal to ensure maximum recruitment of peritoneal capillaries in children.

Acknowledgments

This study was supported by the Swedish Medical Research Council (grants 9898 and 13016), the Knut and Alice Wallenberg Research Foundation, and Sahlgrenska University hospital (LUAB313 03).

References