ADEQUACY OF PERITONEAL DIALYSIS IN CHILDREN: CONSIDER THE MEMBRANE FOR OPTIMAL PRESCRIPTION

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The peritoneal dialysis (PD) prescription should be adequate before being optimal. The peritoneal membrane is a dynamic dialyzer: the surface area and the vascular area both have recruitment capacity.

At bedside, prescription is based mainly on tolerance of the prescribed fill volume, and therefore a too-small fill volume is often prescribed. A too-small fill volume may lead to a hyperpermeable exchange, with potentially enhanced morbidity—or even mortality—risks. Better understanding of the peritoneal membrane as a dynamic dialysis surface area allows for an individually adapted prescription, which is especially suitable for children on automated PD.

Fill volume should be scaled for body surface area (mL/m²) and, to avoid a hyperpermeable exchange, for a not-too-small amount. Fill volume enhancement should be conducted under clinical control and is best determined by intraperitoneal pressure measurement in centimeters of H₂O. In children 2 years of age and older, a peak fill volume of 1400 – 1500 mL/m² can be prescribed in terms of tolerance, efficiency, and peritoneal membrane recruitment.

Dwell times should be determined individually with respect to two opposing parameters:

• Short dwell times provide adequate small-solute clearance and maintain the crystalloid osmotic gradient (and, thereby, the ultrafiltration capacity).
• Long dwell times enhance phosphate clearance, but can lead to dialysate reabsorption.

The new PD fluids (that is, those free of glucose degradation products, with a neutral pH, and not exclusively lactate-buffered) appear to be the best choice both in terms of membrane recruitment and of preservation of peritoneal vascular hyperperfusion.


KEY WORDS: Children; fill volume; dwell time; peritoneal membrane; hyperpermeable exchange.

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For a long time, peritoneal dialysis (PD) prescription was based mostly on clinical experience—very empirically—especially for continuous ambulatory PD (CAPD) patients. Better understanding of the peritoneal membrane as a dynamic dialyzer leads to individual prescription (1), especially for children on automated PD (APD). The PD prescription should be adequate before it is optimal.

The bedside PD prescription (1) is based primarily on

• the PD fluid choice (2), considering at least its biocompatibility and its potential ultrafiltration capacity (that is, its osmotic gradient);
• tolerance of the prescribed fill volume, optimized and adjusted using intraperitoneal pressure measurement;
• an objective parameter of tolerance of the filled abdominal cavity (3); and
• the dwell time exchanges (4), allowing not only for dialytic urea purification, but also for dialytic phosphate purification, a more “dwell time dependent” uremic toxin (5). Together, these two solutes are implicated in the achievement of adequate ultrafiltration and blood purification (1).

Nevertheless, considering the “dialyzer”—the peritoneal membrane—in terms of both surface area and vascular area is also of importance (6). In fact, the peritoneal exchange area directly affects adequacy (6). Knowing more about the possibility of both the recruitment capacity of the contact surface area (the “wetted membrane”) and the changes in the vascular surface area with the hope of preserving hyperperfusion (7–11), the PD prescription should progress from adequate to optimal considering the “dialyzer.”

The PD prescription should be individualized and adapted to achieve at least two main targets:

• adequate ultrafiltration, and thereby, prevention of cardiovascular morbidity or mortality, and
• blood purification not solely limited to urea removal capacity (1,5).

**DISCUSSION**

**OPTIMAL PRESCRIPTION OF FILL VOLUME: PRINCIPLES AND PRACTICE**

In adults on CAPD, the intraperitoneal fill volume is usually reduced to prescription of a full dialysate bag (2 or 2.5 L) without adaptive consideration of differences in the patient’s body weight (kg) or body surface area [BSA (m²); Table 1]. In pediatric care, fill volume has to be adapted to each child, considering the wide morphologic differences between infants and adolescents.

The main clinical question related to fill volume prescription is the child’s tolerance of the filled abdominal cavity: What is the fill volume that can be well tolerated? The main adequacy question arising from fill volume prescription is how to avoid a hyperpermeable exchange (12–16), potentially resulting from a too-small fill volume (15–17).

In the mid-1980s, the fill volume was prescribed per kilogram of body weight, with 30 – 50 mL/kg less fluid being used in infants than in older children, and less at the beginning of dialysis than thereafter, leading to relatively small fill volume prescriptions. This limited fill volume concept also led to a false perception of differences in peritoneal permeability between children and adults, with a hyperpermeable peritoneal state being presumed especially in infants (12–15). Scaling of the fill volume by BSA (mL/m²), particularly in infants and small children, avoided hyperpermeable exchanges as defined in a peritoneal equilibration test (12–14).

Fill volume prescription in children should therefore be scaled to BSA and prescribed in a not-too-small amount (1,12–15). A too-small fill volume (1,15–17) is a factor in “functional hyperpermeability,” this state presumably being related to the ratio between the peritoneal exchange surface area and the small amount of dialysate with which it is in contact (6,17). A too-small fill volume prescription can be corrected by a change in the dialysis prescription (1,6,15–17).

The hyperpermeable state is a major risk factor for ultrafiltration failure because of a too-rapid loss of the glucose-related osmotic crystalloid gradient (1–4), an impaired statural growth rate (18), and a discrepancy between urea in a normal high range and creatinine in a normal low range for the parameters of adequacy (1,5,19), all leading to increased morbidity and possibly even mortality (2,15–17).

Conversely, a too-large fill volume may contribute to patient morbidity (1,15,16) by causing complications such as pain, dyspnea, hydrothorax, hernia formation, gastroesophageal reflux with anorexia, and loss of ultrafiltration by enhanced lymphatic drainage. These morbidities can also result in prescription noncompliance. Furthermore, increasing the fill volume over a so-called peak volume will not improve dialysis efficiency, but may even reduce it (1,6).

All in all, fill-volume prescription should be low enough to be clinically well tolerated, but should thereafter consider “dialyzer” (membrane) recruitment. Fill volume can be adjusted under the control of intraperitoneal pressure measurement to achieve adequate ultrafiltration and urea purification, both of which are directly related to the achieved ratio: fill volume to the membrane surface area and vascular area recruited for the exchange (6,17). In children over the age of 2 years, the presumed optimal fill volume should be increased stepwise close to the upper limit of 1400 – 1500 mL/m² for a night exchange in the prone position, while sleeping.

**TABLE 1**

<table>
<thead>
<tr>
<th>Fill Volume Prescription for Children</th>
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<tr>
<td>For children over the age of 2 years, a peak fill volume of 1400–1500 mL/m² could be prescribed in terms of tolerance, efficiency, and peritoneal membrane recruitment.</td>
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<tr>
<td>A too-large fill volume is a factor in non-tolerance. Adjust and determine fill volume enhancement by intraperitoneal pressure measurement (upper tolerated limit: 18 cmH₂O; usual normal pressure: 7 – 14 cmH₂O)</td>
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<tr>
<td>A too-small fill volume is a factor in hyperpermeable exchanges.</td>
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<tr>
<td>The prescription should be individually adapted as the patient’s condition evolves.</td>
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<td>Fill volume affects peritoneal exchange capacity.</td>
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**DWELL TIME DETERMINATION: PRINCIPLES AND PRACTICE**

Dwell duration (Table 2) directly affects dialytic exchange capacity (1,4): short dwell times favor urea purification and ultrafiltration; long dwell times favor creatinine and phosphate purification.

In CAPD, dwell times are by definition long. Therefore, the major risk is loss of the glucose osmotic gradient, leading to ultrafiltration failure and even more dialysate reabsorption by the child, especially in the case of residual polyuric dysfunctional diuresis. To avoid this condition, hypertonic dialysate is often prescribed, despite the potentially enhanced toxicity to the peritoneal membrane, which is related to the amount of glucose degradation products (GPDs) in the fluid (2,11,20). Ico-
TABLE 2
Dwell-Time Exchange Prescription for Children

| Short dwell times enhance ultrafiltration capacity and maintain adequate urea purification. |
| Long dwell times provide better phosphate clearance, but ultrafiltration could be impaired because of time-related loss of the crystalloid osmotic gradient (dialysate glucose disappearance). |
| Kinetic exchange during a dwell is potentially influenced by the composition of the peritoneal fluid and the fill volume. |

The peritoneal vascular perfusion and the density of the functional pores of the perfused capillaries together determine the vascular exchange surface area. This vascular surface area is dynamically affected by factors such as the PD fluid composition and possible inflammatory agents (8,17). It appears that the new, more physiologic PD fluids—GPD-free, not exclusively buffered with lactate, and at neutral pH—offer the best combination in terms of both membrane recruitment and vascular hyperperfusion preservation (6,7,9,10). But the best choice—either mixed lactate and bicarbonate PD fluid, which preserves peritoneal hyperperfusion and possibly enhances fill volume because of lower induced intraperitoneal pressure (7), or pure bicarbonate PD fluid, which potentially affects surface area recruitment and limits peritoneal hyperperfusion (6,9,10)—is not yet clear.

REFERENCES


