Conventional automated peritoneal dialysis (APD) is prescribed as a repetition of the same dwell time and the same fill volume delivered by the cycler during the dialysis session. Nevertheless, it is well recognized that a cycle with a short dwell time and a small fill volume favors ultrafiltration (UF), while a cycle with a long dwell time and a large fill volume favors uremic toxin removal. The use of varied dwell times and dwell volumes, called adapted APD, allows for an optimized peritoneal dialysis prescription with better volume control—that is, both an increased UF volume at a lower metabolic cost [UF per gram of glucose absorbed (mL/g)] and increased dialytic sodium removal resulting in improved removal of uremic toxins (urea, creatinine, phosphate) during dialysis.

Key words
Dwell times, fill volumes, phosphate, sodium, blood pressure

Introduction
Automated peritoneal dialysis (APD) is classically prescribed as a series of recurrent exchanges, each having the same dwell time and fill volume—that is, “conventional” APD. The efficacy of the procedure is commonly evaluated by both the ultrafiltration (UF) and the Kt/V urea achieved (1). We propose a new approach to perform APD: adapted APD (aAPD), in which the dwell times and dwell volumes of the exchanges are varied to achieve more effective dialysis (2,3). Adapted APD is prescribed as an initial sequence of short-dwell and small-fill-volume exchanges to favor UF at lowered metabolic cost [that is, milliliter of UF achieved per gram of glucose absorbed (3)] and a consequent sequence of long-dwell and large-fill-volume exchanges to favor purification, especially phosphate and sodium removal.

Discussion
Impact of the prescribed dwell time on peritoneal dialysis efficiency
Variations in the dwell duration are well known to potentially alter results in terms of both UF and Kt/V urea. In fact, a too-long dwell is a risk factor for decreased UF, because the crystalloid osmotic gradient is time-dependent: that is, as time increases, the osmotic gradient provided by the glucose in the dialysate is progressively lost. Also, a prolonged exchange does not significantly improve urea removal, because the dialysate-to-plasma ratio for urea reaches a relatively flat “plateau.” Conversely, long-dwell exchanges allow for more solute clearance—that is, enhanced dialysate-to-plasma ratios for uremic toxins such as creatinine and phosphate. Although short-dwell exchanges ensure adequate UF because the crystalloid osmotic gradient is maintained, they are not adequate for the clearance of solutes such as creatinine and phosphate, which, compared with urea, need a longer diffusion time. Altogether, in terms of optimizing dwell times, a short-dwell exchange should lead to greater UF capacity, and a long-dwell exchange should favor “saturation” of the dialysate with creatinine and phosphate.

Impact of the prescribed fill volume on peritoneal dialysis efficiency
The fill volume used in a dialysis exchange has also been demonstrated to affect the UF and Kt/V urea achieved. When dialysis is performed with a large intraperitoneal fill volume (IPV), removal of uremic toxins should be improved for two reasons: a larger volume can be drained and therefore the clearance achieved is greater, and the peritoneal surface area available for the exchange is increased (1). But if the IPV is too large, there is a risk that UF will no longer occur and morbidity will increase, at least in part because of an excessively raised intraperitoneal pressure (IPP). Conversely, a small IPV should promote the process of UF because of the potentially low IPP.
Overall, in terms of choosing the optimal exchange volume, a small IPV should promote UF, and a large IPV should increase the removal of uremic toxins to the dialysate.

The aAPD concept

By applying the foregoing principles, we described in 1994 a new way of performing dialysis (2): aAPD, which sequentially uses shorter and longer dwell exchanges with smaller and larger fill volumes.

Prescription of aAPD uses an initial sequence of short-dwell, small-volume exchanges to promote UF (Figure 1). A combination of short dwells with low fill volumes is, however, potentially associated with several risks. First, the proportion of sodium-free UF via the aquaporin 1 channels increases, especially given a higher crystalloid osmotic gradient, and thus could potentially result in salt overload. Second, high dialysate glucose concentrations exert well-described peritoneal and metabolic toxicity. Hence, adequate UF, increased over the initial sequence of aAPD, should preferentially be achieved by optimizing the dwell time: that is, by using a shorter dwell and a smaller fill volume, and by applying a low dialysate glucose concentration (“isotonic” solution) rather than by increasing the glucose concentration (“hyper-tonic” solution). Thereafter, aAPD is prescribed as a sequence of longer-dwell, larger-volume exchanges to favor removal of uremic toxins (Figure 1).

The order of the sequences—initial short dwells with low fill volumes and subsequent long dwells with larger fill volumes—appears to be important for tolerance and for dialysis efficiency. The perception of the large fill volume by the patient is improved because sleep begins during the initial sequence of small fill volumes. Those initial short exchanges promote sodium-free UF and should result in hemoconcentration and thus an increase in diffusion capacity in the subsequent long exchanges with larger fill volume, optimizing dialysis removal of uremic toxins. Furthermore, sodium-free water transport should dilute the sodium content of the residual undrained dialysate before the switch to the long high-volume dwells, thus further increasing the plasma–dialysate sodium gradient and promoting diffusive salt removal. In addition to the recruitment of peritoneal surface area achieved by larger fill volumes and the increased time for diffusion provided by the longer dwell times, the latter factors contribute to an impressive increase in dialysate sodium removal (nearly doubled), which greatly exceeds the 10% enhancement of urea, creatinine, and phosphate removal (3).

The sequence of longer-dwell, larger-volume exchanges in aAPD affects the peritoneal membrane purification capacity, which is presumably influenced by factors such as the better peritoneal surface area recruitment (meaning more small-pore availability and therefore more convective solute-coupled transport), greater space for diffusion (that is, a larger diffusion distance, which presumably affects the peritoneal small-solute transport rate), and a longer time for diffusive mass transport. Nevertheless, a large fill volume might increase the IPP, possibly resulting in back-filtration and reduced net UF. The prescription of large fill volumes should therefore be managed using IPP measurement to avoid the risks of a too-high IPP (4).

Clinical experiences in aAPD

In adults, we performed a randomized crossover controlled study (Figure 2), applying the same total amount of dialysate and the same dialysis session duration, but prescribed either as conventional APD (that is, repetition of the same dwell time and fill volume for several exchanges) or as aAPD (that is, as an initial sequence of short-dwell, small-volume exchanges to promote UF and a subsequent sequence of longer-dwell, larger-volume exchanges to favor uremic toxin removal.
We demonstrated that, compared with the uniform dwell times and fill volumes used throughout a conventional APD session, the variation in an aAPD session results in a 10% increase in the purification of urea, creatinine, and phosphate; and in improved volume control, enhanced UF volume (+100 mL per session), and enhanced dialytic removal of sodium (nearly doubled) leading to lowered blood pressure (3). The UF efficiency—that is, the “glucose metabolic cost” of UF assessed in milliliters for every gram of glucose absorbed—was improved. And the noted discrepancy between the “limited” enhancement to the dialytic removal of the uremic toxins compared with the impressive enhancement to the dialytic removal of sodium seems to result from various factors influencing peritoneal membrane exchange capacity (5–7).

The bedside prescription of aAPD

To prescribe aAPD, the large fill volume should first be determined: For patients more than 2 years of age, a fill volume of approximately 1500 mL/m² body surface area seems to recruit the total peritoneal surface area available for dialysis exchange (6). This large fill volume should be confirmed by IPP measurement to be less than 18 cmH₂O (4). If possible, the largest tolerable fill volume should be applied. The small fill volume should be half the large fill volume.

Next, the short dwell time should be determined. The individual UF time (7) is available from a peritoneal equilibration test, and in children, it is usually between 30 and 60 minutes (2). For patients with normo-permeability, the long-dwell time is calculated as 3–4 times the individual UF time (1,2). In our experience, respecting the prescription of a large fill over a long dwell for the purification sequence of aAPD is of major importance. The prescription has to optimize better recruitment of the peritoneal membrane, especially the number of small pores available for solute-coupled water transport and for dialytic sodium removal (5); the time for diffusive removal of important toxins such as phosphate; and also the diffusion distance from dialysate to blood (affecting, for example, glucose and thus lowering the metabolic cost in terms of milliliters of UF achieved per gram of glucose absorbed).

Summary

The clinical effectiveness of the concept of aAPD was able to be validated both in pediatric and adult patients (2,3), allowing, on the one hand, for optimized volume control (with a lower blood pressure, enhanced UF volume at a lower metabolic cost, and overall, an impressive enhancement of dialytic sodium removal) and, on the other hand, for optimized removal of uremic toxins (not only an increase in Kt/V urea or K creatinine, but also an increase in dialytic removal of phosphate, without incurring any extra financial cost). Considering all those factors, there is no reason to restrict aAPD prescription to selected patients, but to offer this new way of performing peritoneal dialysis to almost all patients.

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