Maintaining Peritoneal Dialysis Adequacy: The Process of Incremental Prescription

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Urea kinetics (weekly Kt/V) greater than 1.7 generally define adequate peritoneal dialysis (PD). Adequacy of PD depends on residual renal function and PD clearance. Preserving residual renal function and peritoneal membrane characteristics helps to maintain PD adequacy.

The dose of PD can be augmented by increasing the total dialysate volume. Greater volume can be achieved by increasing either the fill volume per exchange or the number of exchanges. Increased time on dialysis can be achieved by keeping PD fluid in the peritoneal cavity at all times. Increasing the convective force enhances solute removal with ultrafiltration.

Incremental PD is used during urgent starts and in patients who are newly starting or who have been on PD. Urgent starts require use of frequent low-volume exchanges to avoid leaks at surgical sites. The dialysate volume can be gradually increased provided that no leakage occurs, up to approximately 2 L per exchange on day 14 for an average-size adult. New-start patients require only 1 – 2 exchanges daily if they still have residual renal function. Incremental PD retains patients on PD as residual renal function wanes and peritoneal membrane characteristics change because of dextrose exposure, infection, and inflammation.

Use of a cycler permits patients to achieve adequacy by increasing the volume per cycle and the number of cycles per treatment. Using a non-dextrose-based solution, such as icodextrin, allows patients to achieve adequate ultrafiltration with less dextrose exposure.

Adequate dialysis can be achieved by manipulating the dialysate dwell volume and the frequency of exchanges, and by optimizing ultrafiltration.

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Adequacy, incremental dialysis, prescription, end-stage renal disease

Introduction

Weekly urea kinetics (Kt/V) greater than 1.7 from peritoneal dialysis (PD) and residual kidney function defines adequate PD (1–4). Some authors will note that PD adequacy is not determined solely by urea clearance or Kt/V urea (5,6). Other criteria for PD adequacy include adequate creatinine clearance, normal blood pressure, euvolemic status, correction of anemia, optimal nutrition status, low inflammation, maintenance of electrolytes (sodium, bicarbonate, potassium, phosphorus, magnesium) in the normal range, prevention of cardiovascular events, and prolongation of residual kidney function (5,6).

The adequacy of PD changes with alterations in the peritoneal membrane or residual kidney function. Preservation of the peritoneal membrane and residual kidney function retains patients on PD. Damage to the peritoneal membrane has been reported with inflammation, peritonitis, exposure to high concentrations of dextrose or dextrose degradation products, and exposure to inflammatory factors in the renin–angiotensin–aldosterone or vascular endothelial growth factor systems (7,8).

Needless to say, peritonitis should be avoided by advocating proper PD connectology, preventing and treating exit-site and tunnel infections, and maintaining good bowel hygiene to avoid both diarrhea and constipation. Minimizing exposure to dextrose can be achieved with a low-sodium diet, fluid restriction, and the use of non-dextrose-containing solutions such as icodextrin (9,10). Using PD solutions with a physiologic pH and blocking the renin–angiotensin–aldosterone and vascular endothelial growth factor systems also preserve the peritoneal membrane

(10,11). Avoiding nephrotoxic agents such as nonsteroidal anti-inflammatory drugs, radiocontrast materials, and certain antibiotics (such as aminoglycosides) helps to preserve residual kidney function. Urine output can be maintained with oral loop diuretics. Low and high blood pressure both tend to affect the glomerular filtration rate. Infections in the genitourinary tract negatively affect renal function. Eating a low-protein diet can work in chronic kidney disease stages 1 – 5, but its role is questionable in patients receiving PD, in whom protein loss occurs with dialysis. Individualizing the dialysis treatment to avoid over-dialysis provides solutes for osmotic diuresis.

In the evolution from a new-start to a vintage patient, kidney function gradually wanes and peritoneal membrane characteristics change because of dextrose exposure, infection, and inflammation. Compared with an anuric patient, the new patient requires less PD to achieve adequacy. Hence, incremental dialysis is a consideration for new-start and vintage patients alike.

Discussion

Factors affecting PD prescription

Many factors affect PD prescription. The three main factors are solute transport characteristics, the results of the peritoneal equilibration test (PET), and patient factors such as patient size and position.

Solutes and water cross the cells of the mesothelium and endothelium that line, respectively, the peritoneal cavity and the peritoneal capillaries. The 3-pore model explains solute and water movement (12). The large pores (100 – 200 Å) transport macromolecules. They are few in number and are located on the venular end of capillaries. The small pores (40 – 60 Å) transport small solutes and water. The ultrapores (4 – 6 Å) are transcellular pores that transport water only.

Diffusion curves show that, during PD, solutes move according to size: small molecules transport faster than larger ones, such that blood urea nitrogen transports faster than creatinine, which transports faster than middle molecules. Moreover, solutes move more rapidly within the first few hours and then slowly toward equilibrium (4 – 6 hours for blood urea nitrogen, for example).

The second factor affecting solute transport is the individual's membrane transport characteristics as determined by the PET (13). High and high-average transporters reach a dialysate-to-plasma creatinine ratio of 0.82 – 1.03 and 0.65 – 0.81 respectively. Low-average and low transporters reach a dialysate-to-plasma creatinine ratio of 0.50 – 0.64 and 0.34 – 0.49 respectively. The high transporters have poor ultrafiltration and adequate solute clearance. High-average transporters have adequate ultrafiltration and solute clearance. Low-average transporters have high ultrafiltration and adequate to inadequate solute clearance. Low transporters have excellent ultrafiltration, but inadequate solute clearance.

Ultrafiltration is affected by the dextrose concentration of the PD solution (14). Crystalloid solutions with higher osmolarity tend to filter more fluid. The ultrafiltration occurs rapidly during the first 1 – 2 hours, after which glucose metabolism or dilution, or both, results in less ultrafiltration as the hypertonic state is lost. If the osmolarity of blood exceeds that of PD fluid, then fluid will be reabsorbed. A colloid-containing solution having a macromolecule with a high reflective coefficient (icodextrin) induces ultrafiltration with an isotonic solution (15). Water transports across small intercellular pores. Icodextrin is absorbed through the peritoneal lymphatics and is ultimately metabolized into glucose. Icodextrin solution provides slow, sustained ultrafiltration of approximately 200 – 300 mL during a period of up to 16 hours.

Patient size and position also affect clearance. On average, the peritoneal cavity can tolerate approximately 30 mL/kg without discomfort or effect on lymphatic drainage (16,17). An overfilled peritoneal cavity causes discomfort and risk for hernia and could impede lymphatic drainage. The lowest intra-abdominal pressure is associated with the supine position, followed by the standing position. The sitting position is associated with the highest intra-abdominal pressure (18).

Adjusting the prescription

Manipulation of the factors discussed in the preceding subsection can increase the dialysis dose. The dialysate volume can be increased by increasing either the fill volume per exchange or the number of exchanges. Alternatively, if dialysate is not currently kept in the peritoneum throughout the day, the peritoneum could be used for the entire day, avoiding "dry" periods. Finally, ultrafiltration can be increased by using dialysate with a high dextrose concentration, adding to solute removal during the convective process (19).

To effectively increase the dialysis dose, automated PD, with the patient in the supine position,

can be used to increase fill volume, to increase the number of cycles, and to administer a higher dextrose concentration solution to increase ultrafiltration (20). In addition, a non-dextrose-containing solution can be used during the long day dwell or a day exchange could be added to the increase dialysis dose (21).

Effect of patient characteristics

The dialysis dose changes with alterations in residual kidney function or peritoneal membrane characteristics.

A patient who starts PD urgently requires frequent low-volume exchanges because of concerns that dialysate could leak from unhealed surgical wounds (22). A suggested starting regimen for an average-size adult would be 500 mL per exchange, using a 1- to 1.5-hour dwell period, repeated for 8 hours daily in a recumbent position. If no leaks occur, then the dwell volume can be increased gradually to 750 mL, 1000 mL, 1500 mL, and by day 14, to 2000 mL.

In a patient initiating traditional PD, start with the lowest PD dose needed to achieve a total weekly Kt/V urea of at least 1.7 (23–26). That dose might be achieved with 1 daily exchange if residual kidney function is 8 mL/min, or with 2 exchanges if residual kidney function is 6 mL/min. Because urea kinetics are checked quarterly, the PD prescription can be titrated up as residual kidney function gradually declines.

Data show that incremental dialysis improves patient survival (27) because the patients retain residual kidney function (28). Gradual solute removal by PD preserves residual kidney function because solute osmotic diuresis can occur. Less exposure of the peritoneal membrane to dextrose preserves peritoneal membrane function. Incremental dialysis also decreases patient burnout and improves quality of life and patient satisfaction.

In patients of longer PD vintage, incremental dialysis can retain patient on PD as they lose residual kidney function and peritoneal membrane function because of infection, inflammation, and exposure to dextrose and its metabolic byproducts.

Optimal dialysis requires a combination of long and short dwell periods. Knowledge of the individual's peritoneal membrane transport characteristics aids in determining whether to increase the dialysis prescription by increasing the dwell volume or the number of exchanges. Low and low-average transporters tend to perform better when the dwell volume is increased. High and high-average transporters perform better when the number of exchanges is increased, taking advantage of the steep curve for solute and volume removal during the early part of a dwell.

Knowledge of residual kidney function aids in prescribing either incremental or full-dose PD. An end-stage renal disease–naïve individual tends to have some urine output. In these individuals, if the estimated glomerular filtration rate exceeds 2 mL/min, PD could be initiated at a lower dose. As residual kidney function wanes, the PD dose would be increased. Such prescription is consistent with an incremental dose of PD. In contrast, an anuric patient transferring to PD from hemodialysis because of a failed access would have to start PD at a full dose. Other examples of individuals with residual kidney function who are ideal candidates for incremental PD include those who transfer early from hemodialysis because of a modality change or those with a failing kidney graft.

Despite being on full-dose PD, a vintage PD patient might need an increase in the PD dose to be retained on PD. Depending on the delivery system, an additional cycle might be able to be added during the day using a cycler (known as continuous cycling PD high dose, or continuous cycling PD plus). Alternatively, the patient might manually perform a daytime exchange.

My personal favorite prescription for all patient types includes the use of a cycler and icodextrin. Icodextrin simplifies the PD regimen. Ultrafiltration that is sustained for up to 16 hours reduces the total dextrose exposure and the total solution volume required over 24 hours. Although icodextrin works most notably in high and high-average transporters, similar results can also be seen in low and low-average transporters. Using a cycler allows the patient to perform only one connection at the start of treatment and one disconnection at the end of treatment, thus decreasing patient fatigue and burnout, which reduces the risk of peritonitis and improves quality of life. Because automated cycles occur rapidly while the patient is in the supine position, intra-abdominal pressure is decreased, lowering the risk for hernia formation and obstructed lymphatic drainage. In addition, greater small-molecule clearances can be achieved. If an incremental dialysis prescription is needed, the cycler can gradually increase the delivered volume and frequency, and the dwell time.

Summary
Incremental prescription can be used throughout the PD spectrum, from new-start patients to vintage PD patients. The adequacy of PD can be defined as weekly Kt/V urea or another parameter. Adequacy changes with alterations in residual kidney function and peritoneal membrane integrity. Lower exposure to dextrose preserves the peritoneal membrane and residual kidney function. Icodextrin offers opportunities to lower dextrose exposure while achieving sustained ultrafiltration. The PD cycler offers options for increasing the PD solution dwell volume or frequency. Time on the cycler can also be increased. All of those options facilitate incremental dialysis that can retain patients on PD.

Disclosures
I understand that *Advances in Peritoneal Dialysis* requires disclosure of any conflicts of interest, and I have no conflicts to disclose.

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