Chapter 11
Techniques in Peritoneal Dialysis

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Introduction

Understanding peritoneal physiology and technical innovations in peritoneal dialysis has led to a significant reduction in therapy-related complications over the last four decades. Technology and techniques to perform peritoneal dialysis (PD) have evolved and, in its current form, are reliable, easy to use, and come at an acceptable cost. Also, various regimens and modes of PD allow for social interaction and optimizing PD efficiency in terms of solute clearance and fluid removal. Overall, the successful advances in PD techniques have prompted broader utilization and served as the foundation for major ESKD healthcare reform initiatives in the USA to support further growth of home-based dialysis [1]. We will outline procedural principles and details of variations of flow techniques (tidal, intermittent, or continuous), regimens [intermittent PD (IPD or continuous PD (CPD)], and modes of PD (manual or automated). These strategies allow for using tidal PD (TPD), continuous flow peritoneal dialysis (CFPD), assisted peritoneal dialysis, urgent-start PD, incremental PD, and remote patient monitoring (RPM) in clinical practice [2]. We will also outline various approaches that can further enhance the scope of PD usage in specific clinical situations.

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A. Rastogi et al. (eds.), *Applied Peritoneal Dialysis*,
https://doi.org/10.1007/978-3-030-70897-9_11

PD Technique and Related Glossary

PD Exchange

The PD technique involves stepwise procedures to connect the PD catheter and perform PD exchange. Maintenance of standard aseptic precautions during PD exchanges to prevent PD-related infectious complications is an integral part of PD technique. The success and longevity of PD largely depend on the quality of initial training and how the patient follows the appropriate technique to the last detail.

A typical manual PD exchange consists of several steps [Fig. 11.1]:

- *Drain* (outflow): In this initial step, the indwelling fluid from the previous exchange is allowed to flow into an empty bag. Draining typically takes 10–20 minutes. The amount of fluid drained during each exchange is referred to as drain volume.
- *Fill* (inflow): After the initial "flush before fill," the PD solution is allowed to flow into the peritoneal cavity via the afferent limb of the Y-shaped tubing. This phase usually takes about 10 minutes. PD solutions are usually warmed to body temperature before use. The amount of PD solution used to fill the peritoneal cavity is referred to as fill volume.
- *Dwell*: After filling peritoneal cavity, the PD solution stays for specific dwell time to allow for the solute exchange and ultrafiltration.

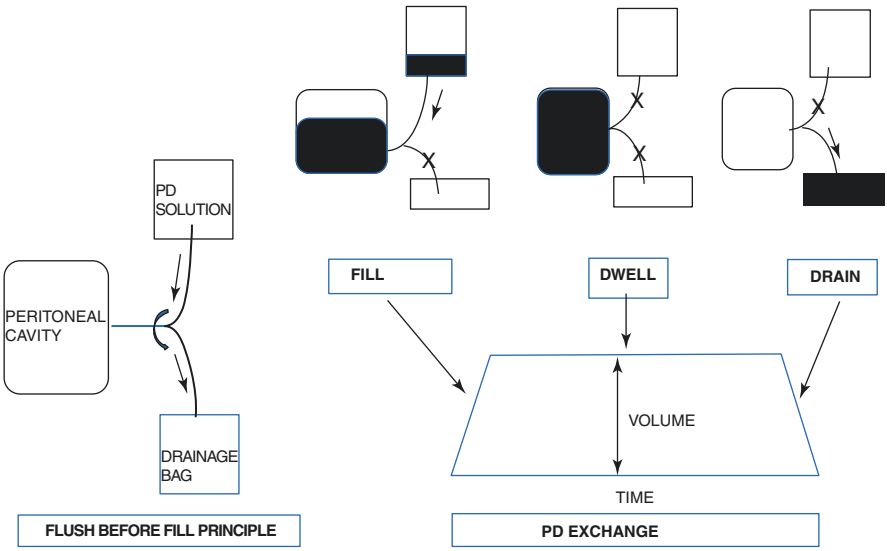

Fig. 11.1 Typical PD exchange demonstrating fill, dwell, and drain phase with relation to intraperitoneal fluid volume and time

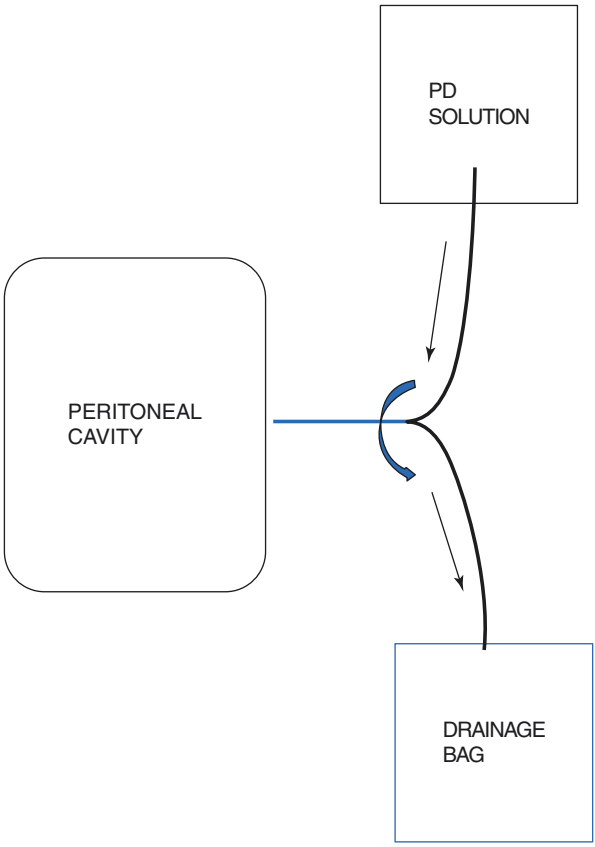

Fig. 11.2 Flush-before-fill principle: PD solution is allowed to flow into the peritoneal cavity via the afferent limb of the Y-shaped tubing before the start of the fill phase of the exchange

At the start of the PD exchange procedure, the "Y tubing set" is connected to the PD catheter via a transfer set and extension tube. The Y-set tube has an afferent limb which is connected with a fresh dialysate bag and an efferent limb with a drainage container attached. The Y system connectology applies the "flush-before-fill" principle [Fig. 11.2]. This approach allows for lines to be flushed free of possible bacterial contamination before each dialysate infusion without opening the system to the outside air (the drain, flush, instill method). First, after connection, a small amount of fresh dialysate (100 ml) is flushed into the drainage bag, and then the peritoneal cavity is drained so that any contaminants introduced during the connection procedures are flushed into the drainage bag and not into the peritoneal cavity. After drainage, the fresh dialysate is infused. This "drain first-infuse later" principle has markedly decreased peritonitis incidence in people doing manual or automated exchanges [3, 4].

PD Technique

PD technique, in its simplest form, relates to the flow pattern of PD fluid during PD exchanges. The intermittent flow and tidal flow patterns are routinely used. Continuous flow peritoneal dialysis (CFPD) has not been adopted into clinical practice despite having mechanistic advantages [2] [Fig. 11.3].

In *intermittent flow PD*, the peritoneal cavity is completely drained before fresh dialysis fluid is instilled. Most currently used PD prescriptions such as CAPD, nocturnal intermittent peritoneal dialysis (NIPD), and continuous cyclic peritoneal dialysis (CCPD) are performed with intermittent flow technique.

In *tidal peritoneal dialysis* (TPD), only a portion of the initial fill volume is drained and replaced by fresh dialysis fluid during each exchange. TPD is a common strategy applied for patients who experience "drain pain" [5, 6]. Drain pain is discomfort in the abdominal/rectal region due to the catheter irritating or exerting a hydraulic suction effect on adjacent visceral organs or parietal peritoneum during the drain period as intraperitoneal volume decreases. This sensation generally diminishes over time but maybe problematic early in the course of PD, particularly in patients on automated peritoneal dialysis. In TPD, a residual volume (usually 15%–25%) is kept in the abdomen at the end of each dwell as a cushion to prevent the catheter from irritating the visceral organs. For example, for a 2-liter fill volume, 80% tidal exchanges would imply that 1600 ml is drained at the end of the dwell, followed by a 1600-ml infusion. The reservoir of fluid left in the peritoneal cavity is finally drained out with the final exchange.

TPD is also used in situations where catheter function is suboptimal and where full drainage takes too much time leading to frequent drain alarms that can interrupt sleep during CCPD/NIPD regimens [5, 6]. Automated cyclers can be programmed to deliver TPD. Tidal PD can also be used in patients who experience pain or discomfort during the fill phase.

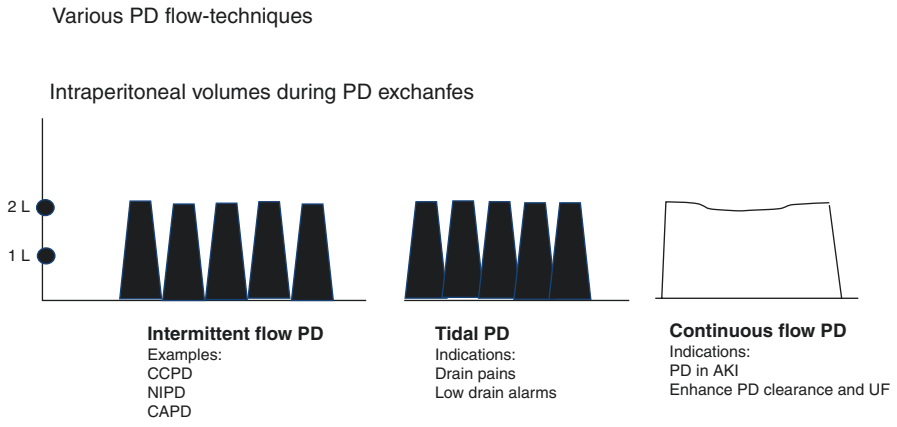

Fig. 11.3 Various PD flow techniques

Continuous Flow Peritoneal Dialysis (CFPD)

In CFPD, a continuous flow of dialysis fluid is instilled, and at the same time, spent dialysate is drained via a separate catheter or lumen. CFPD is a potential strategy to enhance peritoneal clearance and ultrafiltration by achieving a larger concentration gradient between the dialysate and plasma for solute and glucose, respectively [7]. Nourse et al. demonstrated similar outcomes with CFPD compared to conventional PD in pediatric patients with AKI [8]. This concept can theoretically be applied in chronic PD patients with failing membrane function. However, CFPD is rarely used due to challenges associated with the use of double- or dual-lumen catheters, the technical limitations of achieving predictable and real-time ultrafiltration rates, and the requirement of large amounts of dialysate fluid to achieve higher flow volumes. Besides, there is no proven advantage of increasing small solute clearance in terms of survival [9].

Regimen and Modes of Performing PD Exchanges [Fig. 11.4]

A PD regimen entails a systematic plan of how PD exchanges will be performed. PD exchanges can be conducted intermittently (IPD) or continuously (CPD). In IPD regimens, there are periods when the peritoneal cavity is not filled and left dry, while with CPD regimens, the peritoneal dialysate is always present in the peritoneal cavity.

The mode or the methods by which PD exchanges are attained depend on patients' choice, lifestyle, and medical necessity in some situations. Three modes of PD regimens/exchanges are manual (mPD), automated (aPD), and assisted. In some

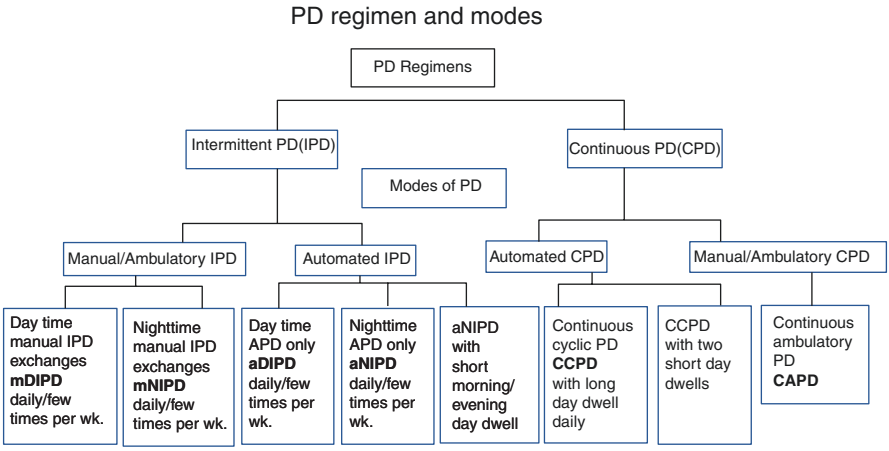

Fig. 11.4 PD regimen and modes

cases, people use both automated and manual methods. On rare occasions, *assisted PD* is a means of supporting people unable to perform their PD, with trained staff or family members assisting with all or part of the dialysis procedure [10].

The PD prescription for an individual incorporates details of PD regimen, mode, fill volume, number of exchanges, and dwell times..

Intermittent PD Regimens

PD exchanges are performed periodically, several times per week. IPD regimens can be done manually (mIPD) or with an automated cycler (aIPD). aIPD regimens allow for patient convenience as the exchanges can be conducted automatically during nights (sleep period) instead of time-consuming frequent manual exchanges. CPD regimens provide better peritoneal small- and middle-molecule clearance compared to IPD regimens as there are many hours in the day where no dialysis is taking place in the latter regimen.

Automated Cycler-Assisted IPD Regimens (aIPD): (Nighttime or Daytime)

Automated nocturnal intermittent peritoneal dialysis (aNIPD) is done with an automated cycler at night only with dry daytime periods. aNIPD is the most preferred combination of PD method and regimen by the patients as it frees up their daytime and avoids the feeling of discomfort while ambulating with daytime dwells. By its nature, aNIPD is performed in a supine position. On rare occasions, daytime IPD (aDIPD) with cycler can also be offered if patients have discomfort with being tethered to the machine during sleep.

Most of the daily IPD regimes are accomplished with automated mode (cycler), and the patients have to be connected to machine for short periods (6–10 hours). Thus, the commonly prescribed aNIPD involves performing machine-assisted IPD regimen at night. In addition, details such as total nightly volume of 8 liters, dwell volume of 2 liters, 4 exchanges over 8 hours, and concentration of PD solutions are specified in aNIPD prescription [Table 11.1].

Manual IPD Regimens (mIPD): (Daytime or Nighttime)

Manual daytime ambulatory PD (mDIPD), i.e., 1–2 daytime exchanges with 2–3-L dwell volumes, nighttime use of single manual PD exchanges most often with icodextrin solution (mNIPD) only, or a hybrid of manual daytime and nighttime

Table 11.1 Typical PD prescriptions

Intermittent PD	Typical daily prescription
Machine-assisted: aIPD (aNIPD or aDIPD)	Total dwell time = 6–10 hours Number of exchanges = 3–5 exchanges Dwell volume per exchange = 2–2.5 liters PD solution: dextrose-based
Manual: mDIPD or mNIPD	Total dwell time = 6–12 hours Number of exchanges = 1–3 exchanges Dwell volume per exchange = 2–3 liters PD solution: Dextrose or icodextrin
Continuous PD	Prescription
CAPD (manual)	Total dwell time = 24 hours Number of exchanges = 3–5 exchanges Dwell volume per exchange = 1.5–3 liters PD solution: dextrose of icodextrin
CCPD (machine-assisted)	Total dwell time = 24 hours aNIPD as above + machine-assisted single daytime exchange of 1–3 liters with either dextrose or icodextrin solution
Enhanced CCPD (hybrid of machine and manual mode)	Total dwell time = 24 hours aNIPD as above followed by the last fill and another exchange some time during the day with a 1–2 liter dextrose or icodextrin solution

exchanges are used such that patients avoid the inconvenience of being connected with an automated cycler [Table 11.1]. These mIPD regimens are often incorporated to facilitate an incremental PD approach (as described below).

Intermittent PD regimens have patient-centered and medical advantages in terms of the following:

- Can be safely prescribed in patients with residual kidney function (RKF). The ADEMEX trial and reanalysis of the CANUSA study have established that peritoneal small solute clearance is not associated with survival on PD [11, 12].
- In patients with residual kidney function (RKF), an incremental PD regimen safely allows patients to do infrequent and shorter PD regimens at their homes. Incremental PD is more acceptable to the patients initiating kidney replacement therapy and attracts them to PD. Incremental PD refers to the practice of incorporating RKF to achieve the total desired solute removal and initially prescribing only a modest dose of IPD, typically 6 L/day or less [13, 14].
- IPD regimens done in a supine position, with low fill volumes, minimize mechanical complications of leaks and hernia associated with continuous elevation of the intra-abdominal pressure [15–17]. If patients at risk for, or with established leaks and hernia, have minimal RKF, then these IPD strategies can allow patients to initiate RRT with PD within 2 weeks of catheter placement (urgent-start PD) and avoid HD [18, 19]. While urgent-start peritoneal dialysis is usually performed with an automated cycler, manual exchanges can be performed if no cycler is available [20].

- Allows for rapid and small-volume exchanges (cycler-assisted). Thus, beneficial in patients with rapid transport status.

These advantages and variations of IPD have allowed prescribers to individualize PD prescriptions based on challenging clinical situations and expand the use of PD as outlined in Table 11.2 and Table 11.3.

Table 11.2 IPD strategies during initiation or early phase of PD start

Potential application	IPD strategy	Advantage
Urgent-start peritoneal dialysis During training period During initial home self-care or assisted treatments	mDIPD aDIPD aNIPD mNIPD (nighttime icodextrin)	Patients often have residual kidney function during this phase Allows for small-volume exchanges and in supine position: Avoids risk of elevated intra-abdominal pressure and thus minimizes the risk of leak
Incremental peritoneal dialysis	mNIPD (night icodextrin) aNIPD mDIPD (1–3-day exchanges) Hybrid of above All of the above can be performed daily or few times a week	Patients often have residual kidney function during this phase
Assisted peritoneal dialysis Increase in uptake of PD in patients with barriers related to self-care PD	aNIPD/aDIPD mNIPD/NDIPD	Easier for relatives or staff to perform 1/2 visits for connection and disconnection
Remote-patient monitoring	aNIPD/aDIPD	Can monitor adherence to therapy and catheter dysfunction

Table 11.3 IPD strategies during long-term maintenance phase of PD

Potential application	IPD strategy	Advantage
Patients with fluid overload-rapid transport status	aIPD: aNIPD, aDIPD	Allows for rapid exchanges to optimize ultrafiltration
Mechanical issues: Post-abdominal surgery, i.e., hernia repair Preexisting hernia not requiring surgery	aIPD: aNIPD, aDIPD	Avoids increased intra-abdominal pressure by using the supine position
Assisted peritoneal dialysis Change in medical condition which is a barrier to self-care PD and at risk for transfer to in-center HD	aNIPD/ aDIPD mNIPD/ NDIPD	Easier for relatives or staff to perform one to two visits for connection and disconnection
Remote patient monitoring	aNIPD, aDIPD	Can monitor adherence to therapy and catheter dysfunction

Continuous Peritoneal Dialysis (CPD) Regimens

Manual CPD, i.e. CAPD

In CAPD, 1.5 to 2.5 liters of dialysis fluid is manually instilled into the peritoneal cavity three to five times daily. Each exchange involves drain, fill, and dwell phases, as described above [Table 11.1]. During the dwell phase, the patient goes about a regular routine until it is time for the next exchange. Even though CAPD involves frequent manual exchanges, it appeals to patients who do not want to be continuously tethered to a cycler or who have issues operating and dealing with machines and alarms. CAPD is also useful when there are flow problems of the dialysis fluid through the catheter. Also, it offers a cheaper option to provide PD in developing countries.

Machine-Assisted CPD, i.e., CCPD

Automated peritoneal dialysis is usually performed using an automated cycler which is programed to deliver three to four exchanges overnight for 6–10 hours, depending on the patient's preference and sleep pattern. During the daytime, the APD patient has the option of either an extended last fill/dwell, usually with icodextrin, or to perform two long (6- to 8-hour) daily dwells (referred to as last fill and midday exchange) [Table 11.1]. At bedtime, the patient connects to the cycler, which drains the day fill, followed by automated night exchange initiation and instillation of the last fill which the patient then carries during the day. In the morning, the patient with last dwell remaining in the abdomen disconnects from the cycler and is free to go about daily activities until bedtime. Most cyclers can be programmed to vary inflow volume, inflow time, dwell time, and drain time. Cyclers also monitor outflow volume and excess drainage (UF volume). Current APD machines have alarms for inflow failure, overheating, and poor drainage.

Continuous peritoneal dialysis regimens are employed to enhance small and middle molecular weight solute clearance and hence used in patients with low or low-average transport status or those with uremic symptoms or with minimal or absent residual kidney function. CCPD with daytime exchange with icodextrin can augment ultrafiltration in patients with rapid transport status.

Aseptic Precautions

During the performance of PD, patients are expected to follow certain aseptic practices under carefully controlled conditions to minimize contamination by pathogens. Practices include hand hygiene, using a mask, and maintaining a safe environment in the area where the exchanges are being carried out.

Excellent hand hygiene by the patient, family members, and members of the healthcare team is essential before initiating the PD exchange procedure. 70% alcohol-based hand rubs for at least 15 seconds is the most preferred method [21]. Handwashing for 15 seconds with antimicrobial soap (4% chlorhexidine) is the most effective method for hand cleansing. Visibly dirty hands require handwashing with soap. Wearing a face mask during a dialysis exchange is recommended. All injection ports should be scrubbed with chlorhexidine and alcohol before injections, and the use of multiple-dose vials (e.g., heparin or potassium chloride) for dialysate supplements should be avoided to decrease the risk of introducing microorganisms [21].

ISPD guidelines recommend that PD patients apply topical antibiotic (mupirocin or gentamicin) cream or ointment to the catheter exit site daily. As mentioned above, space where PD is performed should be kept clean, dry, well-lit, and pet-free [21].

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