Peritoneal dialysis

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Abstract

Peritoneal dialysis is a home-based renal replacement therapy for patients with end-stage kidney disease, offering a degree of autonomy and lifestyle flexibility. After placement of a catheter into the peritoneal cavity under either general or local anaesthetic, the patient is instructed how to perform dialysis exchanges during which dialysate is instilled into the peritoneal cavity. These exchanges can be performed either manually (continuous ambulatory peritoneal dialysis (CAPD)), or using a machine (automated peritoneal dialysis (APD)). During the dialysis exchange, small solutes (e.g. urea, potassium, creatinine) diffuse from the circulation into the dialysate and are removed when the effluent is drained out. With CAPD, the standard approach is to perform four exchanges during the 24-hour period using 2 litres of dialysate on each occasion, although the prescription can be varied according to individual requirements. With APD, the dialysis machine performs repeated exchanges overnight, and the patient has additional daytime exchanges. Water is removed via the osmotic effect of the glucose in the dialysate, although other osmotic agents can also be used, including icodextrin, a glucose polymer, and amino acids. The most common complication is peritonitis; other problems include mechanical difficulties with the catheter, and insufficient removal of water or solute.

Keywords Automated; continuous ambulatory; outcome; peritoneal dialysis; peritonitis; renal replacement therapy; ultrafiltration

Key points

- Peritoneal dialysis is a home-based therapy that allows a degree of autonomy
- The peritoneal dialysis catheter can be used in the acute setting with appropriate care
- The most important complication is peritoneal infection
- Good-quality continuous quality improvement approaches are essential to maintain high standards of care

Introduction

Peritoneal dialysis (PD) has the advantage of being a home-based therapy, offering patients a degree of independence and autonomy in the management of their renal disease, while at the same time avoiding the requirement for vascular access. The patient, or their carer, needs to be trained to perform the dialysis and to recognize common complications. PD is particularly valuable as a therapy in the first years after the development of end-stage renal disease while the patient may still have a degree of residual renal function – although it can be performed successfully in anuric patients.[1] It is used as the first-choice modality of therapy for about 20% of patients started on dialysis in the UK, although its use varies considerably internationally.

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The peritoneal dialysis catheter

An essential requirement for successful PD is the careful placement of an appropriate catheter into the peritoneal cavity under either local or general anaesthetic. Catheters are usually made from silicon or polyurethane and come in a variety of designs. The tip of the catheter is located in the pelvis (Figure 1) with the external part passing through a subcutaneous tunnel and emerging at an appropriately located exit site. Once the catheter has been inserted, it can be used immediately for dialysis if necessary as long as care is taken to reduce the risk of mechanical complications by using low-volume supine therapy for the first period. If time is not critical, it may be preferable to allow the wound to heal before use to reduce the risk of a leak of dialysate from around the catheter exit site. The patient can generally be trained to perform PD as an outpatient, with training being scheduled 2–4 weeks after catheter insertion.

Physiological principles

The principle of PD is that dialysate is infused via the catheter to dwell within the peritoneal cavity for variable periods of time before being drained out, the process being repeated indefinitely. During the dwell, solute moves from the patient's blood to the dialysate across the peritoneal membrane (Figure 2) by diffusing down the concentration gradient. The glucose concentration in the dialysate provides a crystalloid osmotic gradient that draws water across the peritoneal membrane into the dialysate, resulting in the removal of water from the patient. pH is buffered by the absorption of lactate or bicarbonate from the dialysate. Alternative osmotic agents to glucose, including icodextrin (an alternative osmotic agent that is a starch-derived glucose polymer) and amino acid solutions, can be used under certain circumstances.

Removal of solute and water

The amount of urea and creatinine cleared by PD depends on the concentration of solute in the spent dialysate and the volume of dialysate drained out. The clearance of solute can be increased by increasing the volume of dialysate and by scheduling the exchanges to optimize equilibration between dialysate and plasma

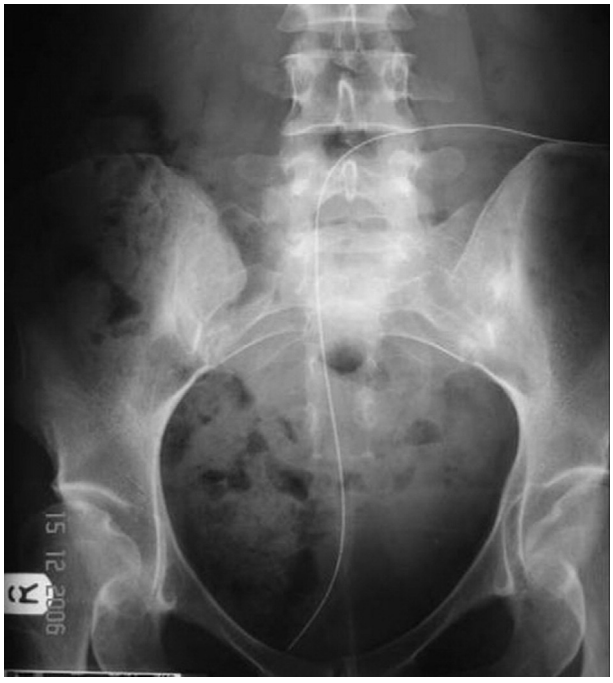


Figure 1 A plain X-ray demonstrating a peritoneal dialysis catheter with its tip located in the pelvis.

solute concentrations. The amount of water removed is adjusted by altering either the glucose concentration in the dialysate or the length of the dialysate dwell (to avoid reabsorption of fluid), or through the use of icodextrin.

The rate at which solute moves across the peritoneal membrane varies between individuals and can be measured using a peritoneal equilibration test. This involves measuring the ultrafiltration volume, the appearance of creatinine and urea in the dialysate and the disappearance of glucose during a 4-hour peritoneal exchange using a standard glucose concentration. Based on the test results, patients can be categorized according to membrane function as fast, average or slow transporters. These categories facilitate decisions about the dialysis prescription. For example, patients classified as fast transporters tend to reabsorb glucose quickly from the dialysate, and can retain fluid from the dialysate unless shorter dwells (e.g. with automated PD (APD)) or higher concentrations of glucose are used. This group can also benefit from the use of icodextrin, which in addition has advantages in diabetic patients.

Techniques and equipment

In its simplest form, PD is a manual procedure (continuous ambulatory PD (CAPD)); the patient is taught to perform dialysis exchanges using a sterile technique. Considerable attention has been given to the connection technology in order to reduce the risk of contamination.

Automation (APD, also known as continuous cycling PD) has brought a number of advantages, allowing several exchanges to be performed overnight while the patient sleeps, thereby reducing the need to perform exchanges during the day. APD can be used to increase the dialysis dose in some patient groups, and to manage difficulties with water removal (ultrafiltration). Modern machines are relatively small, portable and easy to use. APD can also be indicated for social reasons — for example, to allow individuals to work during the day by freeing them from having to perform the daytime exchange (Figure 3).

Remote monitoring technology is a recent development on some APD machines, allowing the delivery of therapy to be reviewed and prescriptions adjusted via a secure online system, as well as displaying patient-entered observations including weight and blood pressure. The evidence base for the impact of this innovation on patient experience and outcomes has still to be built; however, there are clear attractions of being able to respond promptly to therapy problems and to make prescription adjustments more conveniently.

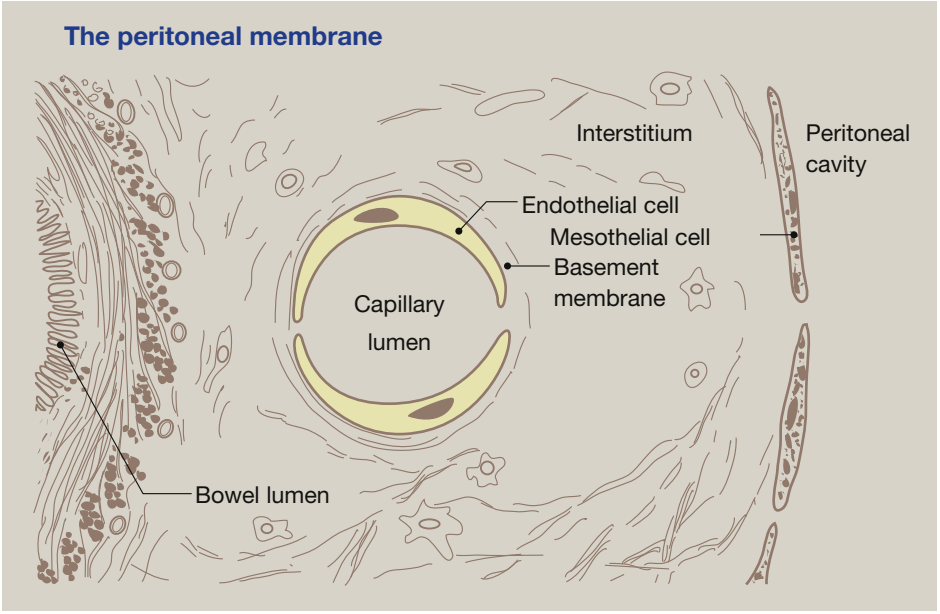
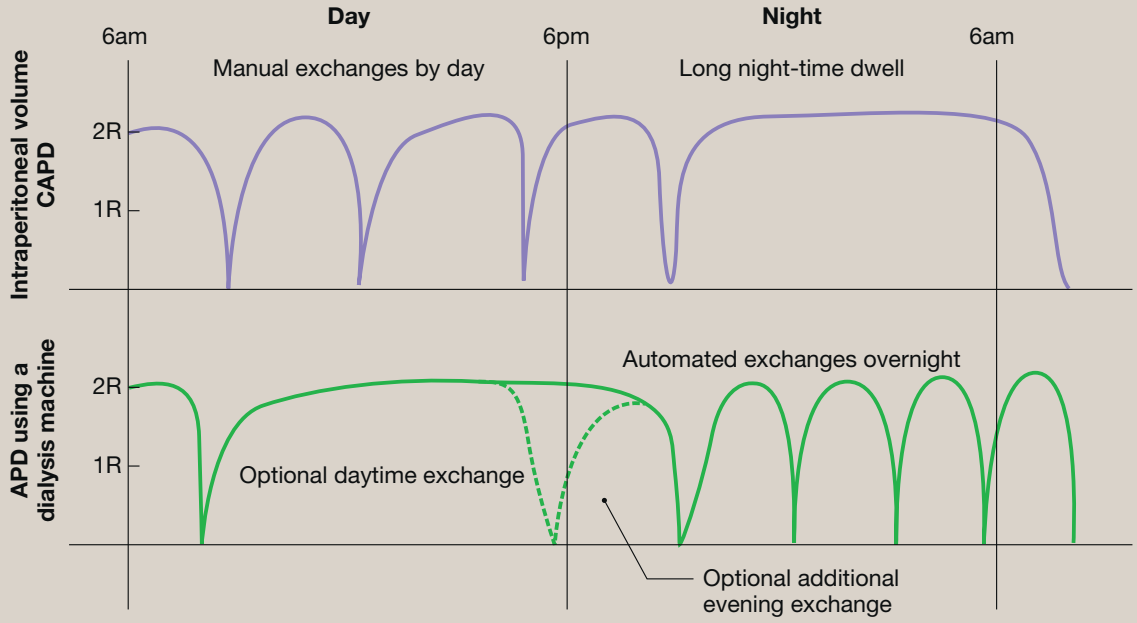


Figure 2 Diagram showing the visceral peritoneal membrane in cross-section.

Types of peritoneal dialysis



Dialysis dose can be augmented by increasing dwell volumes (e.g. to 2.5 litres) or the number of exchanges. This is influenced by the patient's personal membrane characteristics.

CAPD, continuous ambulatory peritoneal dialysis; APD, automated peritoneal dialysis.

Figure 3

Assisted peritoneal dialysis

This is where a (paid) carer performs all or part of the dialysis treatment, thereby enabling more patients to be given their treatment in the community. This is a useful option for frail patients with greater degrees of co-morbidity who would find transport to a haemodialysis unit burdensome. The carer visits the patient on a daily basis to set up the APD machine, removes used dialysis bags, performs basic medical checks and contacts the unit if there are any concerns. Family members can also contribute to this arrangement. PD can be a particularly suitable therapy for patients with poor cardiac function because the more gradual ultrafiltration constitutes less of a haemodynamic challenge than can occur with haemodialysis.

Potential complications of peritoneal dialysis (Table 1)

The PD technique can fail for a variety of reasons, including mechanical problems such as with the catheter or fluid leaks from the peritoneal space, hernias, peritonitis, inability to remove sufficient solute or water (ultrafiltration failure) and social reasons (such as the patient becoming fatigued with the technique or no longer being able to perform it).

Infection

Infection is the most common complication of PD and is an important cause of technique failure. It can take the form of peritonitis or catheter exit site infection. Peritonitis presents typically with abdominal pain and cloudy dialysate, confirmed by an effluent white cell count of >100/microlitre (>50% neutrophils) and by Gram stain and culture. The organism most commonly isolated is *Staphylococcus epidermidis*, which generally causes a mild infection that can usually be managed as an outpatient if the patient is well. More severe infections are caused by *Staphylococcus aureus* or Gram-negative organisms, including Enterobacteriaceae and *Pseudomonas* species or occasionally fungi. Culture-negative peritonitis can result from poor sample collection or culture techniques, recent antibiotic exposure or the presence of fastidious organisms, such as mycobacteria. The audit standard is for an overall peritonitis rate of no more than 0.5 episodes per year at risk,[2] a culture-negative rate of <20% and a primary cure rate of >80%.

Treatment is initially with empirical antibiotics that cover both Gram-positive and Gram-negative organisms administered into the dialysate bag (e.g. vancomycin or a first-generation cephalosporin for Gram-positive organisms, and a third-generation cephalosporin or aminoglycoside such as gentamicin

Advantages and disadvantages of peritoneal dialysis (PD) versus haemodialysis, and potential complications of PD

Advantages
Patient autonomy and independence
Lifestyle advantages (e.g. easier work and travel)
Preservation of vascular access sites
Reduced risk of transmission of blood-borne viruses
Better preservation of residual renal function (in most studies)
Dietary restrictions may be less strict
Lower early graft dysfunction rates after renal transplantation
Disadvantages
Peritonitis and exit site infection
Patient or carer must be able to perform the technique
Technique survival can be limited
Difficult to achieve adequate dialysis in some large patients once residual renal function has failed
Patient can become fatigued with performing the exchanges
Potential complications of PD
Infection — peritonitis, exit site, catheter tunnel
Ultrafiltration failure
Inadequate dialysis
Catheter-related problems — impaired drainage
Leaks and hernias
Constipation
Impaired gastric emptying
Metabolic problems associated with glucose absorption
Long-term changes to the peritoneal membrane, including encapsulating peritoneal sclerosis

Table 1

for Gram-negative organisms) with adjustment of therapy once the sensitivity of the organism is known. If the infection does not resolve promptly (e.g. by day 5), the dialysis catheter is removed to facilitate recovery, with the patient undergoing temporary haemodialysis as required. An important development has been the standardization of treatment guidelines as well as an emphasis on the role of continuous quality improvement to monitor local infection rates, organisms and antibacterial sensitivities.

Infection rates have improved significantly since PD was first introduced, predominantly through developments in connection technology, and more recently from the use of preventive antibiotic creams to reduce the frequency of exit site infection. A 2014 report from Amsterdam documented changes in infection rates over 30 years and found that progress had reached a plateau after a marked improvement over the first two decades. The average peritonitis rate reported in 2017 by the Scottish Registry was 0.7 episodes per year of treatment.[3]

There is increasing global concern about the relationship between the use of broad-spectrum antibiotics and the development of resistant organisms, in particular virulent bacteria including *Escherichia coli* and *Klebsiella pneumoniae* that have the ability to produce extended-spectrum β-lactamases. This presents a particular challenge to PD as a therapy and requires careful management. In the future, point-of-care testing could allow both a more rapid diagnosis of peritonitis and the ability to narrow the spectrum of antibiotic choice earlier than is currently done.

Ultrafiltration failure

This occurs when patients are no longer able to drain sufficient volumes in the dialysis effluent to maintain fluid balance, resulting in symptoms and signs of fluid overload. This becomes more of a problem once urine output declines. A balance has to be maintained between fluid intake and the volume cleared by the dialysis, and most patients require fluid restriction, to which some have difficulty adhering.

Patients can reabsorb fluid from the dialysate for a variety of reasons, including rapid absorption of glucose across the peritoneal membrane (fast transporters), with resulting loss of the osmotic gradient. In these circumstances, the use of higher glucose concentrations, more rapid exchanges, for example through the use of APD, or icodextrin can be beneficial. Absorption of glucose itself can have adverse effects, such as loss of glycaemic control (in diabetes mellitus), disturbance of lipid profile and appetite suppression. Long-term changes to the peritoneal membrane, which occur as a consequence of the dialysis process, can eventually affect the movement of water across the membrane (loss of ultrafiltration capacity).

Mechanical problems

Drainage problems can occur owing to migration of the catheter, so that the tip no longer lies in the pelvis, obstruction with fibrin, clot or omentum, or a leak of fluid from the peritoneal space. Leaks can occur in various ways, including into the anterior abdominal wall via an inguinal hernia, or into the pleural space. Hernias can result from increased abdominal pressure associated with the presence of the dialysate, and the patient may require a period of temporary haemodialysis after repair. However, recurrence of hernias in PD patients is not uncommon — an advantage of using APD is the lower intra-abdominal pressure associated with dialysis in the supine position.

Long-term changes to the peritoneal membrane

PD is associated with long-term changes to the peritoneal membrane resulting from bio-incompatible elements in the dialysate, including glucose degradation products and acidic pH. Newer PD solutions have improved biocompatibility, although these are usually more expensive than the older solutions, and clinical evidence of their beneficial effect on membrane change is lacking.

The most feared long-term complication of PD is encapsulating peritoneal sclerosis, where a thickened fibrotic layer encloses the abdominal contents, potentially leading to impairment of bowel peristalsis and obstruction. This complication is very rare but has a high mortality and appears to be associated with time on PD, glucose exposure and, in some cases, a response to peritonitis. Concerns relating to increasing encapsulating peritoneal sclerosis risk can limit how long patients can continue to use

PD as a mode of renal replacement therapy. Treatment for this condition comes from case-series, but can involve immunosuppressant therapy, tamoxifen, nutritional support and referral to a supraregional specialist service for surgical removal of the fibrotic peritoneum (peritoneolysis).

Outcomes in PD

The 2017 UK Renal Registry report gave a 1-year patient survival for new patients undergoing PD, adjusted to age 60, of 88.3% in haemodialysis and 92.5% in PD, but these data were not adjusted for co-morbidity.[4] Most studies show a similar patient survival for patients on PD and haemodialysis, at least in the first few years of therapy, possibly with an advantage for PD in the first year or two after initiation of therapy. Outcome is determined much more by patient co-morbidity than by modality of dialysis, with the level of residual renal function being a significant contributor. Patients starting on PD in North America tend to be younger, are more likely to be white, with lower co-morbidity and higher levels of education, and more likely to be married and to live further from the treatment centre than those starting on haemodialysis, although there are significant international variations. Most, although not all, studies indicate better preservation of residual renal function with PD than haemodialysis, and it may be this factor that is responsible for the possible early advantage seen with PD. A European study demonstrated 2-year actuarial patient survival for prevalent anuric patients on APD of 78%, with technique survival of 62%.[1]

Several studies have attempted to determine the optimal dose of dialysis that PD patients require. However, although a large study from the mid-1990s suggested an important relationship between small-solute clearance and outcome, this was entirely caused by the component of residual renal function. It became clear from this that peritoneal and renal clearances are not equivalent in determining patient outcome. A more recent randomized controlled trial did not demonstrate a difference between an intervention group that were given an increased dialysis dose[5] and a control group maintained on a stable prescription. There is clearly a minimum dose of dialysis that patients require, but there are several other important factors in determining patient well-being, including ultrafiltration volume, nutritional status and cardiovascular risk and infection rates. The consensus is that treatment should be individualized, while maintaining clearance above a minimum level. ◆

KEY REFERENCES

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FURTHER READING

British Renal Association guidelines and commentaries – https://renal.org/guidelines/.

International Society for Peritoneal Dialysis treatment guidelines – www.ispd.org/guidelines.

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UK Renal Registry audit information – www.renalreg.com.

TEST YOURSELF

To test your knowledge based on the article you have just read, please complete the questions below. The answers can be found at the end of the issue or online here.

Question 1

A 75-year-old man presented with a 2-day history of abdominal pain. He was having regular peritoneal dialysis.

On clinical examination, his temperature was 37.0°C, heart rate 78 beats/minute, and blood pressure 138/90 mmHg. He had diffuse, generalized abdominal tenderness with a cloudy effluent from the peritoneal dialysis catheter.

A sample of effluent was sent for culture. What is the next most appropriate step in his management?

A Urgent surgical review and CT of the abdomen
B Antibiotics by mouth
C A watch-and-wait approach
D Intra-peritoneal antibiotics.
E Broad-spectrum antibiotics intravenously

Question 2

A 42-year-old woman on peritoneal dialysis presented for review. She was well and was performing chronic ambulatory peritoneal dialysis (CAPD) with 1.36% glucose bags. She had recently had a peritoneal equilibration test and had been labelled as a fast transporter.

On clinical examination, she had pitting oedema, her weight had increased by 5 kg, and her blood pressure was 179/95 mmHg.

What would be the most appropriate first step in her management?

A Commence diuretics
B Consider changing to automated peritoneal dialysis
C Change the modality to haemodialysis
D Add in icodextrin
E Adjust her prescription to include 2.27% glucose bags

Question 3

An 83-year-old man presented with the need for dialysis for end-stage kidney disease caused by type 2 diabetes mellitus. He wished to have home-based renal replacement therapy. He had poor mobility and poor fine motor skills from rheumatoid arthritis, and was partially sighted.

What is the most appropriate treatment to offer?

A Hospital-based haemodialysis
B No form of renal replacement therapy (conservative care)
C Assisted peritoneal dialysis
D Chronic ambulatory peritoneal dialysis
E Renal transplantation