

CONTINUOUS AMBULATORY PERITONEAL DIALYSIS (CAPD)

Syed Munib

Nephrology Unit, Department of Medicine, Gomal Medical College, D.I. Khan, Pakistan

Peritoneal cavity was first used for dialysis in guinea pig in 1923 by Ganter.¹ Boen described intermittent peritoneal dialysis (IPD) in 1961, in which dialysis fluid was infused into the peritoneal cavity and then drained out intermittently, in patients with renal failure.² Tenckhoff developed a catheter which led to nightly dialysis using a cycler during 1960 and 1970.³ Until that period peritoneal dialysis (PD) was used only for acute renal failure.⁴

In 1976, Continuous Ambulatory Peritoneal Dialysis (CAPD) was introduced by Popovich et al with 4-6 exchanges per day and long dwell time between the exchanges.⁵ Seattle group used the combination of cyclic and automated PD in two patients, called as continuous automated ambulatory peritoneal dialysis (CAAPD).⁶ Later in 1981 this technique was given the name continuous cycling peritoneal dialysis (CCPD) by Diaz-Buxo.²

There is dramatic rise of CAPD over the last 2 decades. Currently, over 130,000 patients are on CAPD worldwide, comprising 15% of the total dialysis population. It is the most popular form of dialysis in Canada, UK, Hong Kong and Mexico. In Pakistan CAPD is performed for the last few years with more than 100 patients in Karachi, Lahore, Peshawar and Dera Ismail Khan.

Peritoneal dialysis is an intra-corporeal dialysis where Heart act as blood pump and Peritoneum as dialyzer. The total surface area of peritoneum is approximately the surface area of adult skin and blood supply is 60-70 ml/min.¹ Necessary elements for PD are; A healthy peritoneal cavity lined by a functional membrane, an indwelling catheter placed in the peritoneal cavity and dialysis fluid with a delivery system.

PRINCIPLES OF DIALYSIS

Diffusion and Osmosis: The movement of solute molecules from a solution of high concentration to one of lower concentration is called diffusion. Thus molecules such as urea, creatinine, vitamin B₁₂ and phosphates diffuse from blood to dialysate, where the initial concentration is zero. Factors affecting the diffusion are; concentration gra-

dient between the blood and dialysis fluid (the greater the gradient, faster the diffusion) and the surface area and permeability of peritoneal membrane (higher the value the faster the diffusion).

Ultra-filtration: The movement of solvent (water) molecules across the peritoneal membrane controlled by the pressure gradient is called ultra-filtration (UF). High concentration of dextrose in dialysis fluid causes the osmotic pressure for ultra-filtration.

Convection: The solute molecules move in bulk (solvent drag) with the UF of solvent (water). This process is called convection.

Net ultra-filtration: This is the difference in volume of fluid infused into the peritoneal cavity and that drained out.

Lymphatic absorption: A significant amount of water (with solutes) is also absorbed into the lymphatic.

PERITONEAL DIALYSIS CATHETERS

With the development of Tenckhoff catheter, the long term PD was made possible. PD catheter consists of three parts: External segment, Subcutaneous tunnel segment (having two cuffs, the outer one placed just under the skin at exit site and the inner one at the external fascia of the peritoneum) and Intra-abdominal segment with multiple small holes and terminal opening in the peritoneal cavity. PD catheter can be inserted by three techniques: Percutaneous Seldinger technique, Peritoneoscopy and Laparotomy.

PERITONEAL DIALYSIS FLUID

It is delivered in plastic bags with different concentrations.¹¹ (Table-1)

UF volume is dependent on three major factors; Dialysate dextrose concentration (osmolarity), Dwell time and Peritoneal membrane characteristics. Many osmotic agents other than glucose can also be used, like; gelatin, xylitol, sorbitol, mannitol, fructose, dextrane, polyanion, amino acids, glycerol and glucose polymers.

Table-1: Composition of peritoneal dialysis fluid.

Electrolytes	Standard Solution (mmol/L)
Sodium	132
Potassium	0
Calcium	2.5, 3.5
Magnesium	0.5, 1.5
Chloride	96-102
Lactate	35-40
Glucose (g/dl)	1.5, 2.5, 3.5, 4.25
pH	5.2-5.5

PERITONEAL DIALYSIS TECHNIQUES

1- Continuous ambulatory peritoneal dialysis (CAPD): Most commonly used method, employs 4-6 exchanges per day. It only consists of; connecting tubes and solution bags using gravity to fill and drain the peritoneal cavity.

2- Continuous cycling peritoneal dialysis (CCPD): In this technique a cycler loaded with solution bags is used which is connected to the PD catheter just before going to sleep. During night, the cycler makes 4-6 exchanges automatically. At day time 2 L solution is left in the peritoneal cavity with no exchange during the day.

3- Automated peritoneal dialysis (APD): There are different cycler machines which automatically do the exchanges with desired volumes and also measure the UF volume. It also warms the solution and can repeat the outflow if the desired volume has not recovered. Inability to do so triggers the alarm and shuts off the machine.

4- Nocturnal intermittent peritoneal dialysis (NIPD): It is done at night with a cycler with empty peritoneal cavity at day.

5- Tidal peritoneal dialysis (TPD): Peritoneal cavity is filled with solution and after a short dwell time (e.g. 20 minutes) half of the fluid is removed and replaced. It is done continuously so that the cavity is never empty. This method is very costly.

ADEQUACY OF PD

The prognosis of PD depends upon the adequate dose of PD delivered to the patient. There are two common methods for calculating the dose of PD.^{12,13}

1- Weekly creatinine clearance: Total weekly creatinine clearance combines the GFR with the

peritoneal creatinine clearance and normalizes it for a body surface area of 1.73 m².

2- Weekly urea clearance (Kt/V urea): A sum of peritoneal and renal urea clearances, relative to volume of distribution of urea, gives a value of total Kt/V urea.

The minimum dialysis dose needed for:¹²

CAPD: Weekly total creatinine clearance > 60 L / week / 1.73m² and weekly total Kt/V urea > 2.0.

CCPD: Weekly total creatinine clearance > 63L / week / 1.73m² and weekly total Kt/V urea > 2.1.

NIPD: Weekly total creatinine clearance > 66L / week / 1.73m² and weekly total Kt/V urea > 2.2.

Peritoneal Equilibrium Test: Twardowski et al first described a peritoneal equilibrium test (PET) to assess the peritoneal function in terms of the rate of solute transport.^{14,15} Two liter 2.5% dextrose solution is instilled in the empty peritoneal cavity and dialysate samples are taken at 0, 2 & 4 hours to measure its creatinine and glucose concentrations. After four hours dwell time, all of the fluid is removed. Volume is measured and sample volumes are also added to the final volume. A blood sample at 4 hours for creatinine is also taken. Two curves are plotted one for 0, 2 and 4 hours value of dextrose and second for the ratio of dialysate to plasma creatinine concentration. On the basis of PET peritoneal membrane is characterized as; High, High average, Low average or Low transporter.

COMPLICATIONS OF PERITONEAL DIALYSIS

These can be infectious and non-Infectious. Infectious complications include Peritonitis, Tunnel infection and Exit site infection.

Peritonitis: Now-a-days infection rate has declined with improved technique, patient education and antibiotics. One episode of peritonitis in 12-24 months is acceptable according to US Registry Dialysis Data.¹⁶ Two of the following features are essential for the clinical diagnosis of peritonitis:

- Clinical signs and symptoms of peritoneal inflammation, like pain, discomfort, tenderness, rebound tenderness, fever, nausea/vomiting and diarrhea or constipation.
- Cloudy outflow fluid (WBC > 100 cells/mm³), poor drain, loss of ultra-filtration or bloody effluent.
- Positive culture or Gram's stain.

Antibiotics are the main stay of the treatment, added to the dialysis solution. Different dosing regimes are used depending upon the residual urine output and frequency of dosing. Usually loading dose of an antibiotic is infused intra-peritoneally in one liter of solution bag and inflow volume reduced to one liter for few days. The maintenance dose is continued for patients on regular CAPD or CCPD.

Table-2: Common pathogenic organisms and the frequency of their involvement in peritonitis in PD patients.

Organism	Frequency of isolation (%)
Gram positive bacteria	
Staphylococcus epidermis	80-90
Staphylococcus aureus	30-40
Streptococcus viridians	5-10
Streptococcus fecalis	5-10
Gram negative bacteria	
Escherichia coli	5-10
Klebsiella/ Enterobacter spp.	5
Pseudomonas spp.	< 10
Acinetobacter spp	< 5
Mycobacterium spp.	< 5
Other	< 5
Fungi	
Candida spp. Other Fungi	1-10
Culture negative	5-20

Non-infectious complications of PD¹⁷ are related to; PD catheter, insertion technique, dialysis and other.

Complications related to PD catheter:¹⁸ **Outflow problem** - Most common problem in CAPD. It is presented as reduced return of infused volume causing retention of fluid. It can be improved by relieving constipation or by increasing the height of the bed to improve the gravitational pull. Other causes are mechanical obstruction, such as clamp being left on, kinking and accidental suturing of catheter. If there is fibrin seen then heparin (100-500 units/L) can be used in dialysis solution. If catheter is blocked by fibrin plug then urokinase (5000 units) in 40 ml of normal saline can be put in the catheter for 30-90 minutes.

Exit site infection - Pus, redness and discharge at the exit site shows infection which should be treated with antiseptic and local or systemic antibiotics after taking the culture.

Tunnel infection - The signs are redness, pain, swelling and induration at the tunnel site. If antimicrobial therapy is unsuccessful then catheter should be removed to prevent peritonitis.

Complications related to insertion technique: These are perforation, hemorrhage, herniation, and infection. Hernias (mostly in children) and hemorroids are due to increased intra-abdominal pressure by dialysis solution. Reducing the volume in a nightly dialysis may be helpful.

Complication related to PD: These are;¹⁹ Pain (abdomen, shoulder and back), G.I Reflux (nausea, vomiting, poor appetite and feeling of fullness due to increased abdominal pressure due to dialysis solution in the peritoneal cavity), hernia (inguinal, umbilical and ventral), hydrothorax, instillation of hot /cold dialysate, hyper /hypovolemia, hypokalema, malnutrition due to loss of amino acids and proteins in the peritoneal fluid, anorexia leading to reduced protein intake, infections and concurrent medical conditions and under-dialysis.

Other complications: Under dialysis - Inadequate dialysis is a big problem and important cause of PD failure. It is because with passage of time the residual renal function declines and peritoneal clearance alone is not enough to provide adequate dialysis. Other causes are poor compliance, poor technique and loss of peritoneal membrane function.

Membrane failure - It is due to loss of peritoneal membrane functions and can be diagnosed by PET test. It is of three types: Type I failure: The most common form. UF failure in high solute transporters.

Type II failure: Sclerosing peritonitis and inflammation causing decreased membrane permeability and surface area, leading to decreased UF and solute transport.

Type III failure: Excessive lymphatic absorption lead to loss of Net UF.

Cardiovascular complications - Increased cardiovascular complications are seen in CAPD. These are left ventricular dysfunction, LVH and cardiac arrhythmias.

Hemoperitoneum - Most commonly in young ladies due to menstruation. Other causes are renal cell carcinoma, polycystic kidneys, anticoagulant therapy, thrombocytopenia, acute cholecystitis,

sclerosing peritonitis, IgA nephropathy and post colonoscopy.

ADVANTAGES OF PERITONEAL DIALYSIS

- Carried out by the patient in own home. Dialysis exchanges can be modified according to the patient's life style.
- Transport to hospital only needed for clinic or emergency visit. PD fluid can be delivered at home with prior notice.
- Access easy to establish, freedom from mechanical equipment.
- Better preservation of residual renal function than hemodialysis.
- Few dietary and fluid restrictions, decreased incidence of thirst, anemia and better control of hypertension.
- Avoidance of needle prick and systemic heparinization. Chances of hepatitis B and C are less.
- Exit site infection – rarely serious. Peritonitis – usually resolves after catheter removal and is rarely fatal.
- Safer for patients with poor cardiac function and severe ischemic heart disease.

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Address for Correspondence:

Dr. Syed Munib
Assistant Prof. Nephrology
Gomal Medical College
D.I.Khan, Pakistan
Cell: 03008599199
Email: munibsyed@gmail.com