Continuous ambulatory peritoneal dialysis

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Introduced by Popovich et al,[1] in 1976, continuous ambulatory peritoneal dialysis (CAPD) has the potential for affecting the extent to which peritoneal dialysis is used as an alternative procedure for patients with end-stage renal disease requiring dialysis. The concept of CAPD focuses on a continuous internal, portable dialysis system allowing increased mobility for the patient, while at the same time incorporating a basic physicologic approach to dialysis (*Fig. 1*). Our initial experience with CAPD described herein has been most encouraging, warranting continued participation of the patient and additional long-term clinical studies.

Physiologic considerations

Previous reports have suggested that the optimal approach for removing uremic toxins (e.g., urea, creatinine, and phosphorus) could be best achieved through a slower, more prolonged dialysis with lower clearance rates, but longer actual dialysis time.[2] With the implementation of CAPD, a dialysis system is available that utilizes a physiologic, prolonged dialysis capable of stabilizing serum chemistry values through multiple, daily exchanges of commercially prepared dialysis solutions. CAPD utilizes both the actual lower efficiency of peritoneal dialysis and the peritoneal membrane's consider-

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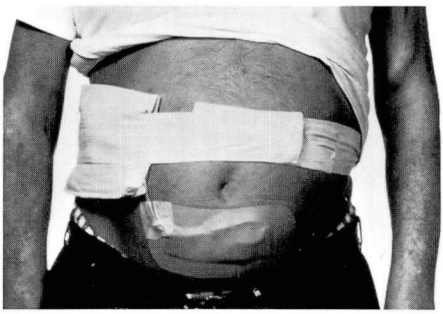

Fig. 1. Wearable, portable device for CAPD, allowing for increased mobility of patients with end-stage renal disease requiring dialysis.

able ability to clear large molecules with relatively low dialysis flow rates.[3]

Although longer dialysis dwell periods ranging from 3 to 8 hours are required, small molecular-weight substances such as urea (60 to 70 daltons), diffuse rapidly across the peritoneal membrane with equilibration during an early phase of the dwell cycle. Larger molecular-weight substances such as creatinine (114 daltons) and middle molecular weight substances such as inulin and vitamin B_{12} (500 to 5000 daltons) diffuse at a much slower rate; equilibration between blood and dialysate does not occur even at 8 hours.[4]

Because of the continuous nature of CAPD, overall efficiency of dialysis is defined in liters of dialysis per week rather than the usual reference for clearance data in milliliters per minute. Moreover, weekly clearances are primarily flow rate dependent for small solutes and surface area-time dependent for larger molecules that are dependent on membrane permeability characteristics or in essence are "membrane limited."[5] The equilibrium between peritoneal dialysis fluid and serum provides for a constant steady state of blood metabolite levels (phosphorus, uric acid, blood urea nitrogen [BUN], creatinine, potassium, bicarbonate, and sodium) that can be accurately monitored by simply measuring the level of solute in the dialysis fluid.[6] Comparisons of solute clearances in dialysis indicate that with CAPD, the clearance of urea is approximately 60% of that noted with hemodialysis, but considerably more than conventional intermittent peritoneal dialysis performed up to 40 hours per week because the dialysis is essentially continuous.[7] CAPD is also more efficient than intermittent peritoneal dialysis or hemodialysis in the clearance of middle molecules. The potential clinical implications of improved middle molecule clearance and the effect in decreasing uremic neuropathy or encephalopathy and anemia warrant further experience with this procedure on larger groups of patients.

Overall, permeability characteristics of the peritoneal membrane may be adversely affected by diabetes. In the initial experience with diabetic patients on peritoneal dialysis, decreased mean clearances of inulin and creatinine were noted due to the reduction in large solute clearance secondary to progressive diabetic vascular disease.[8] Yet, there is a need for better defining the membrane permeability changes that potentially occur in the diabetic on continuous peritoneal dialysis for a long period of time, as well as those factors that alter permeability characteristics in nondiabetic as well as in diabetic patients.

Clinical implications

CAPD offers the patient requiring dialysis increased mobility and independence from machine care. Early enthusiasm has been tempered by a higher incidence of bacterial peritonitis reported from a number of centers and has ranged from one episode in 8 to 38 weeks.[9,10] With the use of plastic bags and a newer titanium perilock fitting,

Table 1. Indications and contraindications for CAPD

Indications	Contraindications
Elderly patients with advanced cardiovascular disease	*Absolute*
Patients awaiting transplantation and fistula maturation	Lumbar disc disease
Patients in whom a reliable vascular access for hemodialysis cannot be maintained	Hypertriglyceridemia
Patients who live alone but desire home dialysis	Widespread abdominal wall infection
Patients with chronic renal failure and symptomatic anemia	Active inflammatory bowel disease
Children with end-stage renal disease	Respiratory insufficiency
Patients who refuse blood transfusions	*Relative*
? Diabetic nephropathy	Poor adherence
	Abdominal hernia
	Colostomy
	? Hypercatabolic state
	Diffuse intraabdominal adhesions
	Ileus

this incidence of infection has decreased. The answer to questions pertaining to long-term effects on membrane permeability both from the constant presence of dialysate and recurring episodes of peritonitis will require further clarification. The early experience with CAPD and clinically evident episodes of peritonitis indicate no significant decrease in permeability exchange characteristics with time.[11]

The general indications and contraindications for peritoneal dialysis are listed in *Table 1.* The indications are generally considered the same as those used for chronic intermittent peritoneal dialysis.[12] Although contraindications are similar, selected problems including pain from lumbar disc disease, higher triglyceride levels in patients with familial hypertriglyceridemia, abdominal hernias, and possibly a colostomy with an increased risk for infection, have been noted as additional contraindications for entering a CAPD program.[13] For the most part, desirable aspects of CAPD pertain to the continuous steady state chemistry values, the performance of dialysis by the patient requiring no assistance, a relatively short training period (4 to 8 days), no need for blood access routes, minimal cardiovascular stress, portable dialysis requiring no facility, physiologic freedom from machine dependence, and an overall improvement in anemia. The undesirable aspects of the procedure relate to the time-consuming technique of having to dialyze 7 days a week, increased protein losses (7 to 20 g/day), higher incidence of peritonitis, hypertriglyceridemia, and urea clearance values, which still approximate only 60% of those noted with hemodialysis.

CAPD methods

The CAPD dialysis system is characterized by the following: (1) establishment of a closed dialysis system incorporating an indwelling peritoneal catheter, exchange tubing, and collapsible plastic dialysis bag (*Fig. 2*); (2) infusion of commercially available dialysate through a permanent indwelling catheter (Tenchkoff, Toronto Western, Goldberg) into the peritoneal cavity; (3) 4- to 8-hour dialysate dwell periods, during which time the individual can perform normal activities while undergoing continuous dialysis; (4) exchange of dialysate* using sterile precautions upon

* *Baxter Laboratories—Dianeal 1.5% or 4.25%*

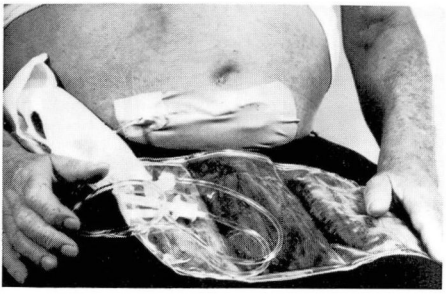

Fig. 2. The basic dialysis system is closed, consisting of the permanent indwelling catheter (catheter is covered by the routine air-strip bandage) connected to the exchange tubing whose spike enters the plastic, collapsible bag to seal the system. This wearable system can be folded and placed in a pouch as in *Figure 1*.

completion of predetermined dwell periods. Exchanges are repeated three to five times daily, 7 days a week.

At the end of each dwell period, dialysate is drained back into the dialysis bag, discarded, and a new 2.0-L bag of dialysate is connected and infused.

Figure 3 shows the three phases of the CAPD procedure: (1) infusion, (2) continuous internal dialysis (dwell period with closure of the clamp folding the plastic bag and placement into the carrying pouch on the abdomen), and (3) dialysate drainage. The actual number of bags the patient uses each day is determined by assessing the blood chemistry values. All patients are trained to incorporate four bag exchanges into their procedure each day. If the serum creatinine level with four exchanges daily is less than 11 mg/dl, the patient is allowed to dialyze with three exchanges each day; if the creatinine level is greater than 16 mg/dl, the patient is advised to dialyze with five exchanges daily. Moreover, if the patient is unable to maintain a steady state BUN level less than 90 mg/dl then the number of exchanges is increased. Usually, adequate control can be achieved with four exchanges every day.

Preliminary experience

Since August 1979, ten patients, eight men and two women, have been trained for CAPD at the Cleveland Clinic. The age range was 20 to 60 years (mean, 45.8 years). The clinical characteristics of this group are listed in *Table 2*. The actual time on CAPD was from 7 months to 3.5 weeks. Patient 1 has returned to in-center intermittent peritoneal dialysis because she did not tolerate 2.0-L exchanges and dwell periods with upright activity, despite the fact that she has tolerated 2.0-L exchanges during intermittent peritoneal dialysis. She also became depressed after leaving the strong social ties in the peritoneal dialysis unit. Pertinent clinical chemistry data are listed for each patient before

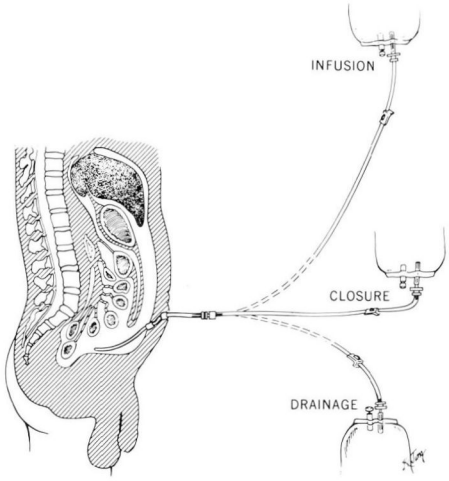

Fig. 3. The three cycles of the dialysis procedure. Infusion of the dianeal solution (1.5% or 4.25%) through the tubing; closure of the clamp and initiation of the dwell phase where the patient collapses the now empty plastic bag and continues activity; drainage cycle whereby dialysate fluid is drained into the bag, disconnected, and discarded. After this cycle a new bag is immediately connected to the tubing spike allowing for the cycle to begin again.

Table 2. Clinical characteristics of 10 patients on CAPD at The Cleveland Clinic Foundation

Patient	Sex	Age, yr	Renal disease	Incentive for CAPD	Previous dialysis/ time on dialysis
1	F	54	Chronic glomerulonephritis	Increased independence	IPD/2 yr
2	M	60	Diabetic nephropathy	Continue working and traveling	IPD/6 mo
3	M	55	Chronic glomerulonephritis	Improve mobility and independence	IPD/22 mo
4	M	32	Chronic pyelonephritis	Healing fistula revision	HD/14 yr
5	M	49	Chronic glomerulonephritis	Recent CVA, significant ASHD, transportation difficulty	IPD/1 yr
6	M	34	Diabetic nephropathy	Patient-physician preference	New
7	F	20	Chronic glomerulonephritis	Jehovah witness with Hgb 5 g	IPD/53 mo
8	M	54	Chronic glomerulonephritis	Patient-physician preference	IPD/3 yr
9	M	41	Diabetic nephropathy	Decreasing vision on HD; significant nausea, desire to return to work	HD/31 mo
10	M	59	Diabetic nephropathy	Continue working and traveling	IPD/1 mo

IPD=intermittent peritoneal dialysis, HD=hemodialysis, CVA=cerebrovascular accident, ASHD=arteriosclerotic heart disease.

CAPD was started along with current data and the number of CAPD exchanges performed each day (*Table 3*). There was overall improvement in creatinine concentrations and increased hemoglobin and hematocrit concentrations in nine of the ten patients. In our patients, the increased hemoglobin and hematocrit values were noted after being on CAPD for approximately 3 weeks. Previous reports[14,15] have indicated that hemoglobin and hematocrit values increase within several weeks after CAPD is begun and then stabilize after some months at a level well above that maintained on prior hemodialysis or intermittent peritoneal dialysis. The choice of CAPD as a preferred method of dialysis in symptomatic individuals with low hemoglobin and hematocrit levels merits further evaluation. It is unclear whether this improvement in these values relates to removal of an unknown dialysis inhibitor factor or stimulation of basic erythropoiesis in the bone marrow through some secondary mechanism.

Among our patients undergoing CAPD, the most common complaints were abdominal distention secondary to 2-L infusion, increased abdominal girth during the 2.0 liter dwell periods, particularly with hypertonic dialysate, postural hypotension and dizziness. Most of the complaints were transient and for the most part, resolved with time. However, patient 4 was started on CAPD because of the delayed healing of a polytetrafluorethylene graft (Gortex) and has experienced continued gastrointestinal distress. A small hiatus hernia, asymptomatic before the initiation of CAPD, has been responsible for increased upper gastrointestinal symptoms in the morning despite a vigorous antireflux medical program. He is with-

Table 3. CAPD clinical chemistry data

Patient		BUN mg/dl	Cr, mg/dl	Phos mg/dl	Ca mg/dl	Tp mg/dl	Albumin g/dl	Hgb g/dl	HcT %	Weeks of CAPD
1*	IPD	71	26	7.3	8.4	6.7	3.6	6.9	22.4	
	4/CAPD†	46	14.4	5.4	9.2	7.2	3.7	8.6	26.1	6
	IPD	73	23	6.2	9.0	6.6	3.6	7.1	22.0	
2	IPD	73	8.2	4.3	8.2	6.3	3.4	9.1	30.0	
	4/CAPD	80	10.0	5.5	9.4	6.7	3.7	13.0	40.4	30
	3/CAPD	87	11.9	6.0	9.2	5.8	3.0	11.4	35.5	
3	IPD	110	16.0	4.3	12.6	6.9	3.9	6.4	16.6	25
	4/CAPD	90	14.0	5.5	9.5	8.0	4.3	8.4	25.7	
4	HD	60	10.0	6.2	10.0	6.0	3.8	8.7	26.8	21
	4/CAPD	40	10.0	4.4	10.2	6.2	4.0	10.0	34.4	
5	IPD	102	20.0	5.7	9.2	6.2	3.7	5.9	18.7	13
	4/CAPD	60	13.1	3.6	9.9	6.9	3.8	12.1	37.8	
6	IPD	99	15.0	3.4	10.6	6.2	2.6	6.3	19.0	
	4/CAPD	48	9.3	3.5	9.2	5.8	3.0	8.6	26.7	16
	3/CAPD	48	9.3	4.0	9.2	6.3	3.2	10.6	32.3	
7	IPD	63	19.0	5.7	10.8	5.3	3.1	5.8	18.5	4
	4/CAPD	67	13.2	4.2	12.2	6.9	4.3	6.9	20.8	
8	IPD	104	29.0	8.6	9.5	6.0	3.9	9.3	29.2	13
	4/CAPD	42	13.0	5.2	9.9	6.2	3.5	9.3	29.2	
9	HD	87	11.7	8.2	9.1	6.0	3.6	7.8	23.2	
	4/CAPD	72	10.8	3.6	9.7	5.9	3.9	8.7	26.7	3
10	IPD	115	8.3	5.9	7.5	6.0	3.3	6.7	20.0	4
	3/CAPD	97	8.8	6.9	8.0	6.4	3.1	9.2	28.0	

* (Patient 1) IPD/CAPD/IPD started on CAPD but returned to IPD after 6 weeks.

† 4/CAPD = number of exchanges every day.

out complaints the remainder of the day and he will probably be maintained on CAPD, at least until the skin wound over the Gortex graft is well healed, at which time he may elect to return to home hemodialysis.

Blood pressures can be controlled at lower levels with less or even total withdrawal of antihypertensive medication while on CAPD. Furthermore, several patients have experienced hypotension necessitating an increase in salt intake to avoid symptoms. This seems to relate to the ease with which ultrafiltration is achieved and fluid is removed during continuous dialysis. Persons with cerebrovascular disease should be observed closely to avoid any degree of postural hypotension during CAPD, which might potentially contribute to CNS insufficiency or to an acute vascular insult. Patients monitor their fluid intake, but with far less scrutiny than they were subjected to when on either hemodialysis or intermittent peritoneal dialysis.

There are few dietary restrictions in comparison to other dialysis modalities. Yet, the dietician plays an active role in assessing the nutritional needs of each patient on CAPD to assure optimal dietary intake and ideal body weight. Because of the increased carbohydrate load from the dialysate fluid used in CAPD, three of our patients have experienced dramatic weight gains. As noted by Nolph et al,[16] glucose absorptions for each 6-hour exchange with 1.5% and 4.25% dextrose dialysis solutions approximate 22 g and 52 g, respectively. Those patients with increased weight gain merit continued attention as to caloric intake, number of hypertonic dialysate exchanges, and planned exercise programs. Nine of the ten patients in

the initial group experienced improvement in appetite and food tolerance. This desirable aspect of chronic dialysis may have future applicability to anorectic patients who are on other forms of dialysis and have difficulty maintaining ideal body weight. Through closely monitoring the protein intake of the CAPD patient the increased protein losses in the dialysate drainage can be easily controlled; total protein and albumin levels therefore remain in a relatively steady state normal range. Also, the dosage of phosphate binders employed in patients on CAPD can usually be decreased probably because of improved clearance of inorganic phosphorus.

CAPD in diabetic patients

Four diabetic patients are undergoing CAPD in our program. Through close monitoring of blood glucose levels during the initial training program, we have formulated a plan of supplemental insulin administration based on the dextrose content of the dialysate used. The results of both the absorption of insulin and the optimal route of administration have been reported;[17–19] however, complete agreement among dialysis centers is still pending. We incorporate both a regular morning dose of subcutaneous insulin and intraperitoneal insulin throughout the day in each bag exchange. Insulin is added to the dialysate immediately before instillation into the peritoneal cavity from which it permeates the peritoneal membrane to enter the portal circulation.

During the first month at home, blood glucose levels are monitored four times daily by a Stat-tek method (Biodynamics) at the time of each bag exchange. We have found the correlation between autoanalyzer-measured serum blood glucose and the Stat-tek tape measurements to be extremely close and this method allows better home control for the diabetic through relatively accurate monitoring of blood glucose. The patient continues to incorporate measurements twice a day after the initial months. The correct dosage is determined by the patient and employed intraperitoneally and subcutaneously after appropriate blood glucose determinations are made. Our diabetic patients have experienced few problems with hypoglycemia or resistant hyperglycemia during CAPD. For periodic evaluations of blood glucose in the morning or evening, regular insulin is combined with intermediate insulin subcutaneously for optimal control. Because two of our diabetic patients have severe diabetic retinopathy, their spouses are performing the actual bag exchanges and Stat-tek blood glucose determinations, allowing each of these patients to enjoy increased mobility and the opportunity to continue working despite retinopathy.

Follow-up care

After the intial training period, each patient is seen in the Outpatient Department every week for the first month, then every month thereafter for in-center tubing change. We are beginning to obtain CAPD clearances on all patients during the initial training period and then follow-up clearances at each visit thereafter.

Thus, we hope to gain a better understanding of the changes in peritoneal clearances in diabetics and in our patients with end-stage renal disease on CAPD. Baseline laboratory data are checked monthly and the status of nutrition is assessed periodically.

There have been two episodes of staphylococcal peritonitis in two patients during the initial 3 months on

CAPD. Both could be traced to breaks in technique. One patient with generalized atherosclerosis obliterans had a cerebrovascular accident, and during the interim before coming to the Outpatient Department weakness in the left upper extremity contributed to repeated contamination of the spike with each bag exchange. It is hoped that with close surveillance during the initial 3 months following training early episodes of peritonitis can be minimized. Bacterial peritonitis is the most common complication in limiting the use of CAPD as an alternative to intermittent peritoneal dialysis or hemodialysis in treating end-stage renal disease. Only through early recognition, improved exchange techniques, and close follow-up can we hope to reduce its incidence.

Summary

Several questions must be answered regarding CAPD. These questions relate to the actual steady state chemistry achieved by this form of dialysis, the optimal number of exchanges and preferred dialysate concentrations needed, the most efficient type of dialysis fluid, the variability of protein losses from day to day, and their fluctuation with peritonitis. These questions will only be answered with increasing experience, both by longer periods of follow-up and larger number of patients dialyzed by this technique.

The incidence of peritonitis should be effectively reduced with improved mechanical innovations and close supervision during training periods for possible lapses in technique. Only prolonged experience with CAPD will determine what changes occur in membrane permeability with time. The long-term effects of CAPD in the diabetic with end-stage renal disease, progressive neuropathy, and retinopathy will be of interest. The opportunity to maintain control of blood glucose and to provide lower steady state chemistry values, higher potential removal of middle molecules and higher blood cell counts promise potentially beneficial effects in the diabetic.

It is hoped that during the next 5 years, many of these questions will be answered, thus allowing the acceptance of CAPD as a viable alternative in the treatment of patients with end-stage renal disease. Because of the simplicity of the basic procedure, the relatively short training period, and improved peritoneal clearances, initial experience with CAPD has been most encouraging. In the months ahead, CAPD has the potential of becoming a widely used treatment for patients with chronic renal failure.

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