Continuous ambulatory peritoneal dialysis in pediatrics: three years' experience at one center

STEVEN R. ALEXANDER, JAMES T. LUBISCHER

From the Department of Pediatrics. Oregon Health Sciences University and the Doernbecher Memorial Hospital for Children. Portland, Oregón. U.S.A.

SUMMARY

Twelve children have been treated with CAPD. Age at onset ranged from two weeks to 15 years ($\bar{x}$ = 6.6 years). Weight ranged from 2.5 kg. to 28.0 kg. ($\bar{x}$ = 15.0 kg.). Renal failure was the result of glomerular disease in 5 patients, hemolitic-uremic syndrome in 2, congenital kidney-urological disease in 2, Jeune's syndrome, cistynosis, and renal-vein trombosis in the remaining 3. Three of these patients had been transplanted unsuccessfully prior to CAPD treatment.

The duration of CAPD ranges from 7 months to 36 months ($\bar{x}$ = 19.3). There have been no deaths on CAPD. Two patients have been transferred to HD, one because an atypical mycobacterial peritonitis, another because she lost peritoneal transport capability after 17 episodes of peritonitis. Daily energy intake (oral intake + glucose absorbed from dialysate) averaged 104 ± 19 % of the recommended for children of the same age. Net daily protein gain (intake − dialysate loses) has been of 2.02 ± 0.64 g/kg/day. Growth in these children averages only two-thirds of normal. Biochemical control has been satisfactory while hematocrits have not been as good as in adult CAPD patients. Eleven patients have suffered one or more episodes of peritonitis (overall incidence of 2.7 ± 2.4 episodes per patient/year). The syndrome of «parent fatigue» has been seen in ten of our families. Almost all patients (11/12) have showed anorexia and periods of poor feeding. Other complications have been: Hypertension (8) and abdominal hernies (5).

Key words: CAPD, Pediatric CAPD.

RESUMEN

Se han tratado con DPCA un grupo de 12 niños urémicos con edades comprendidas entre 2 semanas y 15 años ($\bar{x}$ = 6.6 años) y pesos entre 2.5 y 28 kg. ($\bar{x}$ = 15).

La enfermedad renal primitiva fue glomerular en 5 casos, S. hemolítico-urémico en 2, congénitos 2, S. de Jeunes 1, cistinosis 1, trombosis en vena renal 1.

Tres de estos pacientes habían sido trasplantados sin éxito previamente.

De entre las varias razones para elegir DPCA destaca la larga distancia entre el domicilio y el centro de diálisis pediátrica ($\bar{x}$ = 400 millas).

El tiempo medio de observación ha sido 19.3 meses (7-36).

Dos pacientes abandonaron DPCA: en un caso por peritonitis por micobacteria atípica, falleciendo posteriormente en HD; otro paciente pasó a HD por pérdida de función dializante peritoneal, tras 17 episodios de peritonitis.

Los pacientes muestran pobre apetito, especialmente los de menor edad. El aporte calórico (ingerido + absorbido de peritoneo) es del 104 ± 19 % de lo recomendado para niños sanos de la misma edad. El balance proteico diario es de 2.02 ± 0.64 g/kg/día.

El crecimiento estatural es variable, resultando como promedio de ⅔ de lo normal.

El control bioquímico ha sido satisfactorio, no así el hematológico, aunque los requerimientos transfusionales son menores que en HD.

Todos los pacientes menos uno (11) han padecido 1 o más peritonitis (x̄: 2.7 por paciente/año). La anorexia ha estado presente en alguna ocasión en 11 casos. En 10 de los familiares se ha dado el síndrome de «fatiga de padres», debido a la permanente responsabilidad de realización de los cambios. El resto de complicaciones incluyen: hernias (5), hipertensión (8) e infección del túnel subcutáneo (8).

Palabras clave: DPCA, DPCA pediátrica.

The use of continuous ambulatory peritoneal dialysis (CAPD) in the care of young children with end-stage renal failure began in Toronto [1] and Portland [2] in the latter half of 1978. The early experiences of these first pediatric CAPD programs have recently been reviewed [3-5]. Subsequent reports have described growing pediatric CAPD programs in Birmingham [6,7], San Francisco [8], Paris [9], and Los Angeles [10].

Worldwide, the number of pediatric patients treated by CAPD is unknown. In Europe, 56 children in 1980 were treated by CAPD [11]. Most of these children were treated in the United Kingdom or France. A telephone survey of the pediatric CAPD programs in Portland, Toronto, Birmingham, and Los Angeles revealed that as of February 1, 1982, a combined total of 89 children (≤ 16 years of age) had been successfully started on CAPD in these four programs [12].

The present report will summarize the experience obtained during the first three years of the pediatric CAPD program at Doernbecher Memorial Hospital for Children, Portland, Oregon. Emphasis will be given to CAPD techniques developed for use in infants and small children

TABLE I

CHARACTERISTICS OF PEDIATRIC CAPD PATIENTS
Oregon Health Sciences University

Patient Number	Sex	Age at Onset CAPD	Weight (kg.)	Height (cm.)	Diagnosis	Time on CAPD (Compiled to 2/1/82) (months)
1	M	17 months	9.9	76	Focal glomerulosclerosis	36
2	F	9 months	7.2	67	Rapidly progressive glomerulonephritis Bilateral Wilm's tumor diagnosed during second year of CAPD	32
3	F	5-9/12 years	10.8	86	Congenital hypoplasia/dysplasia Rejection of 2 renal transplants	24
4	M	5-11/12 years	14.1	100	Congenital obstructive uropathy/dysplasia Rejection of 2 renal transplants	30
5	M	15 years	24	115	Focal glomerulosclerosis Rejection of 3 renal transplants	16
6	M	10 years	24	135	Henoch Schonlein's nephritis	21
7	M	13-5/12 years	22	133	Focal glomerulosclerosis Rejection of 1 renal transplant	22
8	M	5-6/12 years	18	102	Recurrent hemolytic-uremic syndrome	17
9	F	23 months	7	72	Recurrent hemolytic-uremic syndrome	11
10	M	14 years	28	134	Jeune's syndrome; Rejection of 1 renal transplant	9
11	M	7-6/12 years	15	106	Cystinosis	7
12	F	Premature newborn (36 wks gestation; began CAPD @ 2 wks after birth)	2.5	48	Renal vein thrombosis/presumed renal cortical necrosis	7

for whom standard «adult» CAPD systems are inappropriate.

Patient Population

Twelve children are the subjects of this report. Characteristics of these young CAPD patients are summarized in Table I. Age at onset of CAPD ranged from two weeks to 15 years (mean = 6.6 years, four infants < 24 months). Weight ranged from 2.5 kg. to 28.0 kg. (mean = 15.0 kg., four infants < 10.0 kg.). There are four girls and eight boys.

Renal failure was the result of a variety of underlying conditions (see Table I). Of interest is Patient 2, an infant who developed end-stage renal failure as a consequence of rapidly progressive glomerulonephritis at 9 months of age. During her second year on CAPD she was found to have bilateral Wilm's tumors. She continues to do well on CAPD 9 months after bilateral nephrectomy/resection of tumors, radiotherapy to the tumor beds, and ongoing chemotherapy. Should she remain free of metastatic neoplastic disease for two years, renal transplantation will be undertaken.

Prior therapy for renal failure in all 12 patients is presented in Table II. For eight children, CAPD was the first dialysis method used, although two had rejected primary renal transplants. Renal failure management immediately prior to starting CAPD was: center hemodialysis = 2 patients; center intermittant peritoneal dialysis = 1 patient; rejection of renal transplant = 3 patients; conservative management = 6 patients.

Reasons for choosing CAPD included patient age and size, family desire to do home dialysis, long distances between homes and the pediatric dialysis center, reluctance to uproot or separate the family so that the child could move to Portland for center dialysis; previous unpleasant or complicated center hemodialysis treatment experiences; unavailability of home hemodialysis for small children in our region; and physician/medical team enthusiasm for CAPD in our center.

Duration of CAPD (Table I; compiled: February 1, 1982) ranges from 7 months to 36 months (mean = 19.3 months). Two children have received cadaveric transplants on CAPD. Patient 4 promptly rejected his third transplant and remains highly sensitized. His family wishes to postpone consideration of another transplant indefinitely. Patient 8 received his first transplant (cadaveric) only 3 weeks prior to preparation of this report. He has experienced two episodes of severe rejection and is presently back on CAPD. Two children are currently awaiting cadaveric transplants; both have high titers of cytotoxic antibodies. Patient 1 is scheduled to receive his father's kidney in 3 months, the time chosen by the family. Two infants are considered below optimum size and age for transplantation. Three families have elected to postpone consideration of renal transplantation for at least one year for various reasons.

In summary, while successful renal transplantation remains the goal of therapy in our program, the advent of CAPD has been followed by reduced pressures to obtain a transplant. A further goal is now the successful maintenance of children on CAPD for prolonged periods, if necessary, while optimum conditions for transplantation are pursued.

TABLE II

PRIOR THERAPY FOR RENAL FAILURE AMONG 12 PEDIATRIC CAPD PATIENTS Oregon Health Sciences University

Rejection of 1 haplo-identical transplant	2
Rejection of 2 cadaveric transplants	2
Rejection of 3 cadaveric transplants	1
Hemodialysis	3
Intermittent peritoneal dialysis	1
Conservative management	6

TABLE III

GEOGRAPHIC DISTRIBUTION OF PEDIATRIC CAPD PATIENTS

Patient	Hometown	Distance from CAPD Center in Portland (miles)
1	Grants Pass, Oregon	250
2	Eugene, Oregon	110
3	Hillsboro, Oregon	15
4	Springfield, Oregon	115
5	Roseburg, Oregon	177
6	San Diego, California	1,100
7	Portland, Oregon	5
8	Cascade Locks, Oregon	57
9	Salem, Oregon	40
10	Hamilton, Montana	700
11	Anchorage, Alaska	2,150
12	Aloha, Oregon	15

Mean = 400 miles

TABLE IV

AVERAGE DAILY ENERGY INTAKE IN SIX YOUNGEST CAPD PATIENTS

Patient/Age	Dietary Intake * (cal/kg.)	Dialysate Dextrose absorbed (cal/kg.)	Total Intake (cal/kg.)	% RDA
1. 17 mos.	90	25	115	109
2. 9 mos.	106	22	128	121
4. 5 years	76	6	82	96
8. 5 years	49	11	60	70
9. 2 years	98	18	116	110
12. Newborn	110	28	138	120
Mean	88 ± 23	18 ± 8	107 ± 30	104 ± 19

* Calculated from 3-day diet histories.

TABLE V

PROTEIN BALANCE IN SIX YOUNGEST CAPD PATIENTS

N = 16 studies - data averaged for each patient

Patient/Age	Daily Protein Intake * (g/kg.)	Dialysate Protein Losses (g/kg.)	Net Protein Intake (g/kg.)	SUN mg/dl.	CAPD Drain Volume (c.c./kg/d.)
1. 17 months	2.97	0.329	2.64	73	222
2. 9 months	1.42	0.355	1:07	52	184
4. 5 years	2.35	0.396	1.95	49	63 ***
8. 5 years	2.43	0.181	2.25	78	156
9. 2 years	3.02	0.309	2.71	73	217
12. Newborn	1.78	0.258	1.52	15	248
Mean	2.33 ± .64	0.305 ± .076	2.02 ± .64	57 ± 24	211 ± 66

* Calculated from analysis of 3-day diet histories provided by parents and inpatient hospital records.
*** Does not include average urine output of 45 c.c./kg/d.

The regional nature of the Oregon CAPD program is reflected by Table III which lists the distances our patients live from the CAPD center in Portland. The ability to manage patients at such great distances is an attractive feature of CAPD, but successful care seems to require at least the following:

1) Extensive involvement of the child's local pediatrician or family physician as an essential member of the CAPD team.

2) Training and equipping families so that they can function independently and self-sufficiently, especially those living in rural areas.

3) Intensive telephone follow-up care by the CAPD staff to maintain contact and provide necessary supervision. All families are contacted at least once each week regardless of how long they have been in the program.

4) Gradual extension of the four-week interval between follow-up center clinic visits to 8-10 weeks for stable patients.

TECHNICAL CONSIDERATIONS AND MANAGEMENT GUIDELINES

Indications for CAPD

In our center, CAPD is now the pediatric dialysis method of choice. The only absolute contraindications are an inadequate peritoneal transport capability or insufficient peritoneal space (e. g., oomphalocele or gastroschisis). CAPD has been successful in several patients who have previously had multiple abdominal surgical procedures. We have no experience with patients with ileostomies or colostomies but would consider these patients on an individual basis. Laterally placed ureterostomies should present no difficulties for CAPD care.

A family situation suitable for home dialysis is important, but we have been unable to devise a method to reliably predict the CAPD capability of any given family. Single parents do quite well when dialysis schedules are coordinated with work schedules. Our policy is to offer all families the opportunity to learn CAPD if they are motivated to do so. All families to date have successfully completed CAPD training and there have been no subsequent dropouts for psychological or stress-related reasons.

TABLE VI

AVERAGE LABORATORY VALUES OBTAINED ON 12 PEDIATRIC CAPD PATIENTS AT THEIR MOST RECENT CLINIC VISITS

	Mean	Range among 10 children
Glucose	109.0	88.0-140.0 mg/dl.
BUN	77.0	44.0-122.0 mg/dl.
Creatinine	8.2	3.9- 12.5 mg/dl.
Na	139.0	134.0-144.0 mEq/l.
K	4.6	3.3- 6.1 mEq/l.
Cl	101.0	92.0-107.0 mEq/l.
CO_2	22.0	20.0- 28.0 mEq/l.
Uric acid	7.8	5.4- 12.5 mg/dl.
Calcium	10.2	8.6- 11.9 mg/dl.
Phosphate	5.6	3.3- 7.1 mg/dl.
Total protein	5.8	5.1- 7.0 g/dl.
Albumin	3.3	2.3- 4.1 g/dl.
Cholesterol	222.0	184.0-315.0 mg/dl.
Alkaline phosphatase	242.0	89.0-551.0 Iu/l.
LDH	317.0	153.0-441.0 Iu/l.
SGOT	35.0	15.0-101.0 Iu/l.
Hct	23.0	18.0- 29.0 %
Triglycerides	282.0	152.0-405.0 mg/dl.
Magnesium	2.9	2.5- 3.8 mg/dl.
Daily dialysate protein losses	.302 g/kg/day *	.175-.469 g/kg/day

* In absence of peritonitis.

TABLE VII

LINEAR GROWTH IN PEDIATRIC CAPD PATIENTS

Patient	Sex	Age at Onset CAPD	Total Months on CAPD	Growth Rate (cm/yr.)	Percentage of Predicted Normal Growth Rate
1	M	17 months	36	2.9	32
2	F	9 months	32	5.6	56
3	F	5-9/12 years	24	4.25	74
4	M	5-9/12 years	30	5.4	105
5	M	15 years	16	2.25	50
6	M	10 years	21	3.0	50
7	M	13-5/12 years	22	12.0 **	213
8	M	5-6/12 years	17	6.1	101
9	F	23 months	11	7.6	95
10	M	14 years	9	4.0	67
11	M	7-6/12 years	7	2.0	50
12	F	Newborn	7	16.0 **	68
				Mean = 4.31 cm/yr. ± 1.83 0.36 cm/mo.	68

** Not included in calculation of mean growth rates.

TABLE VIII

COMPLICATIONS SEEN IN 12 PEDIATRIC CAPD PATIENTS

	Patients
Peritonitis Candida - 1 Atypical mycobacterial - 1	11
Exit site infection lasting > 4 weeks	7
Tunnel infection resulting from trauma to the superficial cuff	6
Parent fatigue syndrome	10
Anorexia, periods of poor feeding	11
Inquinal, umbilical, and incisional hernias	5
Hypertension	8

TABLE IX

SUMMARY OF PERITONITIS IN PEDIATRIC CAPD PATIENTS

Patient	Months on CAPD	Episodes of Peritonitis	Incidence episodes per patient year)
1	36	7	2.30
2	32	5	1.88
3	24	17	8.5
4	39	1	0.4
5	16	8	6.0
6	21	3	1.7
7	22	3	1.64
8	17	5	3.5
9	11	2	2.2
10	9	1	1.3
11	7	0	0
12	7	2	3.4
TOTALS	232	54	Mean 2.7 ± 2.4

TABLE X

TABULATION OF CAUSATIVE ORGANISMS IN 54 CULTURE-POSITIVE EPISODES OF PERITONITIS

Staph epidermitis	16
Staph aureus	11
Strep viridans	6
Enterobacter cloacae	3
Pseudomonas species	4
Acinetobacter species	5
Klebsiella species	3
Candida parapsilosis	1
Mycobacterium avium intracellularae	1

Pediatric CAPD Catheter Design and Placement

From its beginning, our program has used Tenckhoff catheters placed by open technique in the operating room. The procedures used in the first two years of our program were devised in association with Edward S. Tank, M. D., Chief, Pediatric Urology, and have been reported in detail elsewhere [13]. These procedures were recently revised based on further experience obtained during the past year.

We use only «adult» size Tenckhoff catheters, even in the smallest of our patients (weight = 2.5 kg.). The intraperitoneal portion is trimmed at time of placement so that the tip lies in the pelvis. The single Dacron-felt cuff is glued at a point only 3 cm. above the first catheter side holes. This cuff is placed at the peritoneum. A pursestring suture closes the peritoneum and incorporates the cuff, passing through the substance of the cuff at its base. This suture pulls a «collar» of peritoneum around the base of the cuff, creating a water-tight seal.

TABLE XI

PERITONITIS IN PATIENTS ON HOME-PREPARED VS. HOSPITAL PHARMACY-PREPARED SMALL VOLUME DIALYSATE BAGS

Patient Number		Home Prepared			Hospital Pharmacy Prepared		
		Episodes	Total Exchanges	Incidence	Episodes	Total Exchanges	Incidence
	1	5	4,710	942	2	685	343
	2	4	4,270	1,068	0	385	—
	3	13	3,650	281	4	670	168
	4	0	4,125	—	0	320	—
	9	2	840	420	0	185	—
	12	1	200	100	0	30	—
Totals	6	25	17,795	712	6	2,275	379

TABLE XII

PERITONITIS IN PATIENTS ON STANDARD CAPD EXCHANGE USING TRAVENOL-SUPPLIED DIALYSATE BAGS

Patient Number		Episodes	Total Exchanges	Incidence
	8	5	2,075	415
	5	8	3,115	389
	6	2	2,675	1,338
	10	1	630	630
	11	0	270	—
Totals	5	16	8,765	548

A short, straight subcutaneous tunnel (4.5-6.5 cm.) is constructed, passing at a slight angle from the midline. Previously, a second, or subcutaneous cuff was routinely placed. During the past year, six patients suffered trauma to this cuff and subsequently developed erosion and/or tunnel infections requiring replacement of the catheter. We no longer use this second cuff.

Catheter placement also involves indentification and repair of inquinal and umbilical hernias, partial omentectomy in selected cases, radiographic demonstration of proper positioning and successful intraoperative initiation of peritoneal dialysis to insure that the catheter is functioning and the peritoneal closure is water-tight. Details of this procedure are presented in an accompanying report.

Initiation of CAPD

CAPD begins at time of catheter placement and continues without interruption thereafter. We begin with four to six exchanges of 1.5 % dialysate at a volume of 15 c.c./kg. These exchanges each last only one hour and occur while the child is recovering from the effects of general anesthesia. Dialysate contains 500 units Na heparin per liter and 125 mg. cepharin per liter for these first six exchanges only. Some patients may require more prolonged intermittant peritoneal dialysis to restore fluid and/or metabolic balance.

Exchange volume and dwell periods are then gradually increased over the following 5 to 7 days. By the end of this first week of CAPD, the goal is to have reached maintenance exchange volumes of approximately 35 c.c./kg. and a regular CAPD schedule of five exchanges/day (4-hour exchanges through the day and an 8-hour exchange overnight). This continuous initiation method has several advantages:

TABLE XIII

SUMMARY OF PERITONITIS INCIDENCE IN PEDIATRIC CAPD PATIENTS

	Number Patients	Total Episodes	Total Exchanges	Incidence (exchanges per episode)	Incidence (patient-months per episode)
Home-prepared bags	6	25	17,795	712	4.75
Hospital pharmacy-prepared bags	6	6	2,275	379	2.5
SUBTOTALS	6	31	20,070	647	4.3
Standard CAPD bags	5	16	8,765	548	3.7
TOTALS	11	47	28,835	613	4.1

1) There is a gentle removal of excess body water to approach the patient's dry weight;
2) antihypertensive medication can often be either discontinued or reduced in dosage;
3) because the new catheter is never left in a «dry» peritoneal cavity, the likelihood of omental encasement and obstruction is reduced;
4) CAPD training can be started early as parents and child learn by observing exchange procedures performed by the nursing staff; and
5) the child is stabilized on a CAPD maintenance regimen by the end of the first week allowing further training to be done as an outpatient.

The Pediatric CAPD Training Program

Training begins during the first week after catheter placement while the child is still hospitalized for stabilization on CAPD. Daily training sessions are required to teach the basic CAPD procedures:
1) the continuous peritoneal dialysis process
2) small-volume bag preparation and use
3) safe dialysate bag exchanges
4) meticulous exit site care
5) sterile connecting tubing change
6) dialysate culture methods
7) procedures required in recognition and treatment of peritonitis
8) a daily routine of brief but careful assessment and recording of the child's weight, blood pressure, exit site and tunnel condition, and quality and quantity of dialysate fluid drained at each exchange.

Detailed protocols used in our program to train parents and older children in these techniques are included as an Appendix.

Maintenance CAPD

For children with negligible residual renal function ($C_{cr} < 5$ ml/min/1.73 m^2), dialysis is prescribed at 35-40 c.c./exchange, 5 exchanges/day and fluid balance maintained by adjusting dextrose concentrations to yield at least another 35-40 c.c./kg/day in net ultrafiltration. Children with more residual renal function were placed initially on the same regimen and then reduced to 4 exchanges/day if possible. Phosphate binders, supplemental calcium, calcitriol, water soluble vitamin supplements, folic acid and occasionally iron supplements were also given.

A technique was developed in 1979 to allow home preparation of small-volume dialysate exchange bags using empty blood bank transfer packs filled from two liter bags of dialysate. As dialysate has become available from the manufacturer in smaller volume bags, fewer of our patients are required to make small-volume bags at home.

Because ultrafiltration requirements varied widely among our young patients, we felt it desirable to be able to adjust dialysate dextrose concentration between the only available strengths: 1.5 % and 4.25 %. Parents are taught to add prescribed volumes of 50 % dextrose to the 21 bags of dialysate prior to filling their small-volume bags. Sodium lactate must also be added along with the 50 % dextrose to avoid diluting these electrolytes.

Parents originally prepared each day's supply of small-volume bags on a daily basis. Now up to 14 days' supply is prepared at a single procedure and the small-volume bags kept frozen until the day they are to be used.

RESULTS

Mortality and Drop-Out Rates

There have been no deaths on CAPD. Patient =5 contracted atypical mycobacterial peritonitis (mycobacterium avium-intracellularae) and was forced to discontinue CAPD [14]. He was begun on hemodialysis and died four months later from acute complications of vascular access surgery superimposed on disseminated atypical mycobacterial infection. Patient =3 lost peritoneal transport capability after 17 episodes of peritonitis in 24 months on CAPD. She is now maintained on hemodialysis.

Nutrition

Children on CAPD have poor appetites. We first prescribed «unlimited diets,» encouraging protein intake and high calorie foods. We hoped children would spontaneously consume at least 2.0 grams protein/kg/day and more than 70 % of the Recommended Dietary Allowance (RDA) for total calorie intake, an energy intake level which has been reported to be associated with improved growth in children on chronic hemodialysis [15]. We have since learned that all children require dietary supplementation to achieve these goals. All infant formulas must be fortified and every child's diet supplemented, using fats, carbohydrates and high biologic value protein supplements.

Small infants exhibit impressive anorexia. We recently resorted to chronic naso-gastric tube feeding in the youngest infant (age 6 months) when dietary goals could not be met in any other way.

Nutritional data on the six youngest CAPD patients in our program are summarized in Tables IV and V. Parents provided three-day diet histories from which 24-hour dietary intake was averaged. Each child was assessed during two to four separate three-day periods over 6 to 24 months of stable CAPD. Collections of 24-hour

dialysate drains and, where appropriate, 24-hour urine output were analyzed for total protein, urea nitrogen, and glucose. Sixteen separate evaluations in the six young children are summarized in Tables IV and V.

Daily energy intake averaged 104 ± 19 % of the RDA for children of the same chronologic age and sex (Table IV). Dextrose absorbed from the dialysate provided an average of 18 ± 8 kcal/kg/day. Protein intake averaged 2.33 ± 0.64 grams/kg/day (Table V). Dialysate protein losses were 0.305 ± 0.076 grams/kg/day for a net protein gain each day of 2.02 ± 0.64 grams/kg/day.

Biochemical Control

Average laboratory values obtained on the 12 patients at their most recent CAPD clinic visits are listed in Table VI.

Transfusions

Many adult CAPD patients regain near normal hematocrits and few require transfusions. This has not been the case for our patients (although transfusions are given far less frequently to children on CAPD than to children on hemodialysis). We give 10 c.c./kg. of packed red blood cells when hematocrits approach 20 %. Our patients require transfusions at an average interval of 3.0 months (range: 1.6 to 6.0 months).

A marked improvement in appetite has been observed to follow transfusions. Hypertension may occur during transfusions in children whose blood pressures are normally well controlled.

Growth

Table VII presents cumulative growth data for all 12 patients. Growth rate is normalized to cm/year. The patient's growth is then compared to that of a child of the same sex and bone age whose growth rate is at the 50th percentile for children in the United States. The results of these comparisons are presented as the «percentages of predicted normal growth.»

While 7 of 12 patients have linear growth rates at least two-thirds «normal,» none have shown catch-up growth. One boy has shown a normal pubertal growth rate and development of secondary sexual characteristics.

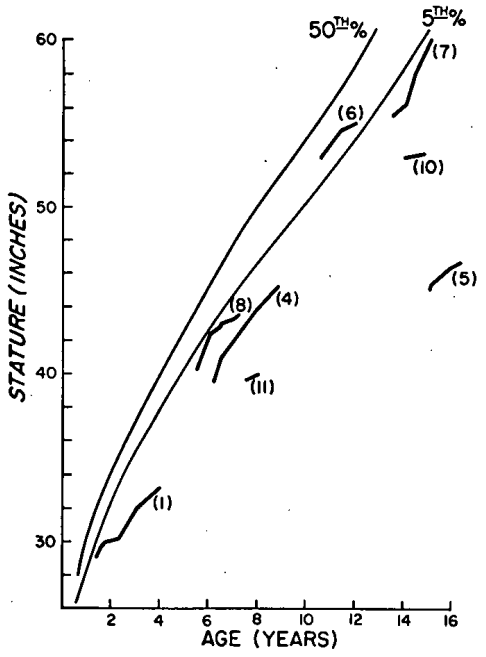
Figures 1 and 2 depict linear growth for chronologic age (after onset of CAPD) for the 11 older children.

Complications

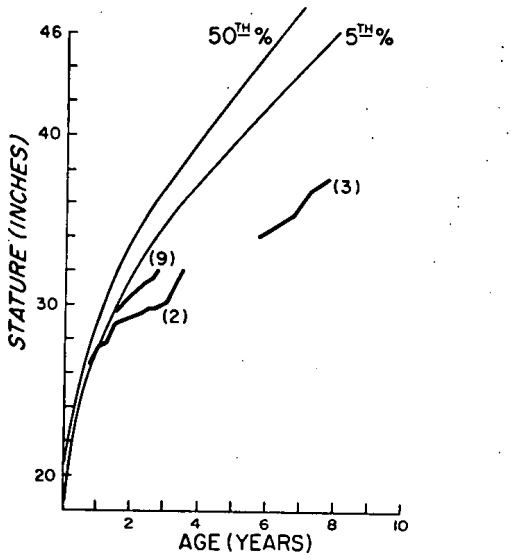
Table VIII lists complications most often seen in these 12 patients. Infections continue to be the most troublesome problems in our patients. Only one of our patients has never had peritonitis.

FIGURE 1

BOYS: STATURE FOR CHRONOLOGIC AGE



GIRLS: STATURE FOR CHRONOLOGIC AGE



Details of the peritonitis experience in this patient group are given in Table IX. Overall incidence is 2.7 ± 2.4 episodes per patient-year with a range from 0 to 8.5 episodes per patient-year. Causative organisms are listed in Table X reflecting the expected predominance of gram positive organisms.

The syndrome of parent fatigue has been seen in the majority of our families and may now be predicted to occur around the third to the seventh month at home on CAPD. It can also recur at variable intervals thereafter. Our program stresses training of multiple care-givers who can assist and relieve the parents of their tedious and boring CAPD exchange responsibilities. By the second year of CAPD, our families have settled into routine which includes CAPD procedures as simply a

part of daily life. As families relax and begin to discover the convenience and relative freedom provided by CAPD, this acceptance process is accelerated.

Hypertension has remained a problem for eight of our patients, but to a much lesser degree than seen in these same patients prior to going onto CAPD.

Peritonitis and the Home-Prepared Small-Volume Dialysate Container

Impetus for development of the small-volume bag technique came from the necessity to provide a CAPD method suitable for very small children living far from the CAPD center — often in small communities without hospital pharmacies capable of preparing small-volume bags. Our hospital pharmacy will prepare these bags for our patients, but at a substantial cost. Preparation by parents at home is estimated to result in a savings of $7,000/year in Oregon. Similar costs have been reported from the University of Alabama in Birmingham [16].

Advantages of small-volume dialysate bag preparation at home include:

1) CAPD may be tailored to the individual needs of pediatric patients by adjusting volumes and dextrose concentrations as required.

2) Home preparation results in substantial savings when compared to hospital pharmacy preparation.

3) For rural patients the problems of transporting and storing up to a one-month supply of hospital prepared small-volume bags are eliminated.

4) Travenol will provide the additional home supplies required as part of regular monthly CAPD deliveries upon appropriate request.

Disadvantages include:

1) Two additional training days are required to teach the family to perform this procedure.

2) 30-45 minutes of additional effort by one parent every 4-7 days are required to prepare each supply of bags.

3) There are risks of errors in prescription and preparation, especially when dialysate additives are used.

4) There is a theoretically increased risk of peritonitis following contamination since the procedure is not done under a laminar flow hood.

This last concern prompted a more detailed review of the influence of the method used to prepare small-volume bags on the incidence of peritonitis in our patients. We compared the following:

1) Homemade bags, by parents.

2) Hospital pharmacy prepared small-volume bags.

3) Travenol-supplied 500 c.c. and 1.000 c.c. bags.

Six children used small-volume bags prepared either at home or in the hospital pharmacy. All six children were exposed to both sources. Five other children used bags exclusively provided by Travenol and were considered a control group.

It is theoretically possible to acquire peritonitis each time a new bag is used. Incidence of infection has been shown to vary directly with the number of exchanges done. It is not known whether the infecting organism is introduced when the small-volume bags are prepared, when the CAPD exchange is made, or at some other time (via the blood stream or lymphatics).

Tables XI, XII, and XIII summarize the findings in this retrospective review. Patients 1, 2, 3, 4, 9 and 12 were exposed to both home and hospital prepared bags. The incidence of peritonitis was calculated using episodes of infection and total bags used in each method. A similar tabulation is made for five patients who used only Travenol supplied bags. There were 25 episodes of peritonitis in 17,795 exchanges using home prepared bags, 6 episodes of peritonitis in 2,275 exchanges using pharmacy prepared bags and 16 episodes of peritonitis in 8,765 exchanges using Travenol supplied bags. Incidence of infection is not significantly different among all three subgroups ($p > 0.22$). We conclude that peritonitis risk remains concentrated at the bag exchange procedure and is not influenced adversely by the use of home prepared small-volume dialysate bags.

CONCLUSIONS

CAPD has been successfully used in Oregon in the treatment of infants and children with renal failure for three years. The method appears to be safe, effective and well tolerated by children and their families. While a successful renal transplant remains the goal of CAPD therapy, the advent of CAPD techniques suitable for infants and small children allows maintenance of these patients for indefinite periods while optimum size, age and general health are attained in preparation for renal transplantation.

Programs caring for small infants may wish to use the home-prepared small-volume dialysate bag method described. As a wider choice of dialysate volumes and osmolalities become available, the need for such techniques will decline but probably never disappear altogether. The use of CAPD in newborn infants is a case in point.

Growth in children on CAPD is variable but averages only about two-thirds of normal despite efforts to insure adequate dietary protein and total energy intake. Preliminary studies in six small children suggest that these patients are in positive nitrogen balance. Whether dialysis as prescribed for our patients is truly «adequate» remains to be determined. Further investigation is needed in the areas of nutrition, appetite, basic metabolism, dialysis kinetics and growth and development of children maintained on CAPD. The successful development of pediatric CAPD techniques has provided an

exciting new perspective from which to examine these fundamental issues.

REFERENCES

1. BALFE, J. W., and IRWIN, M. A.: «Continuous ambulatory peritoneal dialysis in pediatrics». Proceedings of an International Symposium, Paris, 1979. Continuous Ambulatory Peritoneal Dialysis. Ed. by M. Legrain. *Excerpta Medica,* Amsterdam, 1980, pp. 131-136.
2. ALEXANDER, S. R.; TSENG, C. H.; MAKSYM, K. A., and TALWALKAR, Y. B.: «Early clinical experience with continuous ambulatory peritoneal dialysis (CAPD) in infants and young children». *(Abstract) Clin. Res.*,28: 131A, 1980.
3. BALFE, J. W.; VIGNEUX, A.; WILLIAMSEN, J., and HARDY, B. E.: «The use of CAPD in the treatment of children with end-stage renal diseade». *Peritoneal Dialysis Bulletin,* 1: 35, 1981.
4. BALFE, J. W.; IRWIN, M. A., and OREOPOULOS, D. G.: «An assessment of continuous ambulatory peritoneal dialysis (CAPD) in children. CAPD Update». Ed. by J. W. Moncrief and R. P. Popovich. Masson Publishing USA, New York, 1981, pp. 211-220.
5. ALEXANDER, S. R.; TSENG, C. H.; MAKSYM, K. A.; CAMPBELL, R. A.; TALWALKAR, Y. B., and KOHAUT, E. C.: «Clinical parameters in continuous ambulatory peritoneal dialysis for infants and children». In: *CAPD Update.* Ed. by J. W. Moncrief and R. P. Popovich. Masson Publishing USA, New York, 1981, pp. 195-210.
6. KOHAUT, E. C.: «Continuous ambulatory peritoneal dialysis: a preliminary pediatric experience». *Am. J. Dis. Child,* 135: 270, 1981.
7. KOHAUT, E. C., and ALEXANDER, S. R.: «Ultrafiltration in the young patient on CAPD». In: *CAPD Update.* Ed. by J. W. Moncrief and R. P. Popovich. Masson Publishing USA, New York, 1981, pp. 221-226.
8. POTTER, D. E.; McDAID, T. K.; McHENRY, K., and MAR, H.: «Continuous ambulatory peritoneal dialysis (CAPD) in children». Proceedings ASAIO, Chicago, 1981 (in press).
9. GUILLOT, M., and BROYER, M.: «Continuous ambulatory peritoneal dialysis for children». Proceedings, Second International Symposium on Peritoneal Dialysis, Berlin, 1981 (in press).
10. SALUSKY, I. B.; FINE, R. N.; NELSON, P.; BLUMENKRANTA, M. J., and KOPPLE, J. D.: «Nutritional status of pediatric patients undergoing CAPD». *(Abstract) Book of Abstracts of the 14th Annual Meeting,* American Society of Nephrology, 1981, p. 50A.
11. BROYER, M.; DOUCKERVOLCKE, R. A.; BRUNNER, F. P.; BRYNGER, H.; JACOBS, C.; KRAMER, P.; SELWOOD, N. H.; WING, A. J., and BLAKE, P. H.: «Combined report on regular dialysis and transplantation of children in Europe, 1980». *Proceedings, EDTA,* 18: 60, 1981.
12. Personal communications: J. W. BALFE, M. D., Hospital for Sick Children, Toronto; E. C. KOHAUT, M. D., University of Alabama in Birmingham; R. N. FINE, M. D., University of California in Los Angeles.
13. ALEXANDER, S. R., and TANK, E. S.: «Surgical aspects of continuous ambulatory peritoneal dialysis in infants, children and adolescents». *J. Urol.,* vol. 127, 1981 (in press).
14. PULLIAM, J.; VERNON, D.; ALEXANDER, S. R.; HARTSTEIN, A., and GOLPER, T.: «Atypical mycobacterial peritonitis in CAPD patients». *Am. J. Med.* (submitted for publication, 1982).
15. SIMMONS, J. M.; WILSON, C. J.; POTTER, D. E., and HOLLIDAY, M. A.: «Relation of caloric deficiency to growth failure in children on hemodialysis and the growth response to caloric supplementation». *N. Engl. J. Med.,* 285: 653, 1971.
16. SHMERLING, J.; KOHAUT, E. C., and PERRY, S.: «Cost and social benefit of CAPD in a pediatric population». In: *CAPD Update.* Ed. by J. W. Moncrief and R. P. Popovich. Masson Publishing USA, New York, 1981, pp. 189-194.