

Residual Renal Function in Children Treated with Continuous Ambulatory Peritoneal Dialysis or Automated Peritoneal Dialysis—A Preliminary Study

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Our study assessed the influence of mode of dialysis [continuous ambulatory peritoneal dialysis (CAPD) or automated peritoneal dialysis (APD)] on residual renal function (RRF). The study retrospectively examined 30 children [15 on CAPD, mean age: 8.85 ± 5.15 years; and 15 on APD, mean age: 10.17 ± 3.63 years (nonsignificant)], followed for at least 12 months, for whom these methods were initial mode of treatment. Arterial hypertension was found in 80% of the children on CAPD and in 67% on APD. Parameters that were analyzed included 24-hour urine output; residual glomerular filtration rate (GFR); adequacy based on total weekly Kt/V urea and creatinine clearance; and hemoglobin, total protein, serum albumin, daily proteinuria, medications used, and causes of end-stage renal disease.

After 12 months of decline in urine output, residual GFR was higher in children on APD ($p = 0.06$, nonsignificant). The difference in adequacy between CAPD and APD was nonsignificant, but a higher volume of dialysate was used in APD ($p < 0.01$). Proteinuria was present in 9 children on CAPD and in 6 on APD. In CAPD, we observed a negative correlation between the volume of dialysate and duration of treatment ($p < 0.01$, $r = -0.79$); in APD, a positive correlation ($p < 0.0001$, $r = 0.89$) was observed. In APD, we observed negative correlations between residual diuresis and duration of treatment

($p < 0.0001$, $r = -0.9$), serum albumin ($p < 0.05$, $r = -0.6$), and volume of dialysate ($p < 0.001$, $r = -0.83$). Residual renal function was better preserved in children with a glomerulopathy or a familial or hereditary renal disease than in those with pyelonephritis.

Our results suggest that RRF is better preserved in children with a glomerulopathy or a familial or hereditary renal disease, especially in those treated with CAPD. Further studies are needed in larger groups of patients.

Key words

Residual renal function, children, APD, CAPD

Introduction

Preservation of residual renal function (RRF) in patients receiving renal replacement therapy (RRT) is associated with decreased cardiovascular risk because of lowered blood pressure, decreased left ventricular hypertrophy (1), better correction of anemia (1,2), improved fluid balance, and easier removal of the sodium load (3). Of particular note, preservation of RRF in adult patients results in better peritoneal dialysis (PD) adequacy, with a higher clearance of small molecules (4), improved phosphate elimination (2), and improved clearance of intermediate molecular weight toxins such as β_2 -microglobulin with a concomitant decrease in its plasma level (5). Increased preserved RRF appears to be associated with a better quality of life for patients receiving RRT (6). Studies showed better-preserved RRF both in adults and in children undergoing PD than in similar patients treated with conventional hemodialysis (7–9).

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The aim of our study was to assess RRF in children with end-stage renal failure treated with continuous ambulatory PD (CAPD) or automated PD (APD).

Material and methods

Our retrospective study included 30 children (13 girls, 17 boys) with end-stage renal failure and preserved residual diuresis who were treated during 1992–2008 in two pediatric dialysis units at the Department of Pediatrics and Nephrology, Medical University of Warsaw, and the Department of Pediatric Nephrology, Collegium Medicum of the Jagiellonian University, Cracow. In all these patients, CAPD or APD was the initial mode of RRT, and the duration of follow-up was at least 12 months. Overall, the mean age of the study subjects was 9.51 ± 4.43 years (range: 4 days – 17.25 years). Continuous ambulatory PD was used in 15 children aged 8.85 ± 5.15 years, and APD in 15 children aged 10.17 ± 3.63 years. Causes of end-stage renal failure in the study group included familial or hereditary renal disease ($n = 10$, including 7 children with polycystic kidney disease), primary or secondary glomerulopathy ($n = 6$), pyelonephritis ($n = 5$), miscellaneous renal disease ($n = 5$), congenital disease ($n = 3$), and interstitial nephritis ($n = 1$).

Continuous ambulatory PD was performed using twin-bag dialysis fluid sets (Baxter Healthcare Corporation, Deerfield, IL, U.S.A.). In the CAPD group, 4–5 daily exchanges were routinely performed, each using 30–50 mL/kg dialysate containing 1.36% glucose during the daytime and 3.86% glucose during the night.

Automated PD was performed at night, using the HomeChoice cyler (Baxter Healthcare Corporation) and 5–8 exchanges over 12 hours. In 7 children, an additional exchange was required during the day. The daytime exchange used dialysate containing 2.27% glucose in 3 patients for 5–12 months (mean: 9 months) and icodextrin dialysate (Extraneal: Baxter Healthcare Corporation) in 4 patients for 4–12 months (mean: 5.75 months).

In all children, RRF was assessed at baseline and at 12 months of treatment based on a 24-hour urine collection expressed as milliliters per kilogram of body weight and the estimated preserved glomerular filtration rate (GFR) of the native kidneys [calculated as the average of the creatinine and urea clearances from a 24-hour urine collection, expressed in milliliters per minute for a body surface area (BSA) of 1.73 m^2].

Adequacy of RRT was assessed by calculating total weekly Kt/V urea (twKt/V) and total weekly creatinine clearance (twCCr). The twKt/V and twCCr were calculated from 24-hour urine and dialysate specimens and a blood sample. Total body water was taken as the urea distribution space (10). Preserved GFR and twCCr were corrected for BSA by the Du Bois and Du Bois formula (11). In addition, we also determined—for all patients at baseline and at 12 months of treatment with PD—height in centimeters, body mass in kilograms, hemoglobin, serum total protein and albumin, proteinuria, and the total volume of dialysate used, including fluids containing 1.36%, 2.27%, and 3.86% glucose and those containing icodextrin.

In addition to the effect of the dialysis modality used (CAPD or APD), our evaluation of RRF also took into account the type of renal disease that caused end-stage renal failure, the presence of hypertension, and the occurrence of dialysis-related peritonitis. We also evaluated the effect of medications used in our patients, including angiotensin-converting enzyme inhibitor, angiotensin II receptor blocker, nonsteroidal anti-inflammatory drugs, aminoglycosides, and erythropoiesis-stimulating agents.

Serum, urine, and dialysate creatinine concentration was determined using a colorimetric method based on picric acid reactivity in an alkaline medium (diagnostic kit from Cormay, Lublin, Poland); serum, urine, and dialysate urea concentrations were determined using an enzymatic urease method; urine total protein concentration was determined using the turbidimetric (Exton) method; serum total protein concentration was determined using the burette method; and serum albumin concentration was determined using protein electrophoresis in cellulose acetate gel (diagnostic kit from Cormay). Cobas-Mira S (Hoffman-LaRoche, Nutley, NJ, U.S.A.) and Vitros 250 and 950 (Johnson & Johnson, New Brunswick, NJ, U.S.A.) analyzers were used. Hemoglobin concentration in venous blood was determined using MD II, MD II Micro Diff II 18, and HmX-AL automated hematologic analyzers (Beckman Coulter, Miami, FL, U.S.A.).

Statistical analysis

Results are expressed as mean \pm standard deviation or as median values with a range. The Kolmogorov-Smirnov test with Lilliefors significance correction was used to test data for normality. Statistical analyses

used the Student *t*-test for normally distributed variables and the Mann–Whitney *U*-test for variables lacking normal distribution. Correlations between parameters were analyzed using linear regression. The Kruskal–Wallis test was used to compare the degree of residual diuresis loss between groups of patients with varying causes of chronic kidney disease. A *p* value less than 0.05 was considered statistically significant.

Results

Table I shows the clinical characteristics of children with end-stage renal failure treated with CAPD or APD. Among the 30 children treated with RRT, high blood pressure was found in 22 (73.3%), including 12 patients treated with CAPD (80%) and 10 treated with APD (66.7%)—a statistically insignificant difference. The most commonly used antihypertensive drugs were angiotensin converting-enzyme inhibitors. Loop diuretics were used in 33.3% of patients, but these agents were administered more frequently (by more than a factor of 2) in the APD group. We found no statistically significant difference in the rate of RRF loss between patients with and without hypertension.

Peritonitis was significantly more common ($p < 0.05$) in children treated with CAPD.

Table II shows mean or median values of the parameters evaluated before initiation of RRT and at 12 months of treatment in the CAPD and APD groups. We found no significant difference in the mean values of residual diuresis in the CAPD and APD groups before RRT initiation. After 12 months of treatment

with PD, diuresis was insignificantly lower in both groups, with a clear trend seen in the APD group ($p = 0.06$). Before initiation of treatment with PD, the mean preserved GFR was insignificantly higher in the APD group. At 12 months, the mean GFR values were insignificantly reduced in both groups, but no patient had reached anuria.

During the 12 months of follow-up, children treated with APD required a higher volume of dialysate to maintain normovolemia and adequate PD. The mean total volume of dialysate was significantly higher in the APD group than in the CAPD group at 12 months ($p < 0.01$). Children treated with CAPD required higher volumes of high-osmolality fluids, with a significant difference in the mean value as compared with that in the APD group at 12 months ($p < 0.01$). Higher ultrafiltration was obtained in the CAPD group than in the APD group, but a significant difference ($p < 0.01$) was found only at initiation of treatment with PD. We found no significant differences in the parameters of PD treatment adequacy (twKt/V and twCCr) between the two groups either at initiation of PD treatment or at 12 months of treatment.

We found no significant difference in mean hemoglobin between the CAPD and APD groups before the initiation of RRT. At 12 months, mean hemoglobin was higher in both groups, with a significant difference in favor of the APD group ($p < 0.05$). Mean serum total protein and albumin at initiation of treatment and at 12 months did not differ significantly either

TABLE I Characteristics of patients treated with either continuous ambulatory peritoneal dialysis (CAPD) or automated peritoneal dialysis (APD)

	CAPD	APD	Overall
Patients (<i>n</i>)	15	15	30
Boys:girls	6:9	11:4	17:13
Age (years)	8.85±5.15	10.17±3.63	9.51±4.43
Arterial hypertension [<i>n</i> (%)]	12 (80)	10 (66.7)	22 (73.3)
Medications (<i>n</i> patients)			
ACEIs	2	11	13
ARBs	0	1	1
NSAIDs	0	0	0
Aminoglycosides	3	0	3
Loop diuretics	3	7	10
ESAs	10	15	25
Dialysis peritonitis (episode:patient–months)	1:22.5 ^a	1:60 ^a	—

^a $p < 0.05$.

CAPD = continuous ambulatory peritoneal dialysis; APD = automated peritoneal dialysis; ACEIs = angiotensin converting-enzyme inhibitors; ARBs = angiotensin II receptor blockers; NSAIDs = nonsteroidal anti-inflammatory drugs; ESAs = erythropoiesis-stimulating agents.

TABLE II Parameters in the two groups of study patients at initiation and after 12 months of renal replacement therapy

Parameter	PD initiation		After 12 months	
	CAPD	APD	CAPD	APD
RRF				
24-Hour urine output (mL/kg)	43.03±22.64	46.74±34.00 ^a	37.52±26.95	34.54±28.57 ^a
Residual GFR per 1.73 m ² BSA (mL/min)	5.13±3.93	7.52±4.15	4.19±2.98	5.69±4.31
24-Hour dialysis data [mL/kg (range)]				
Mean dialysate volume	131.82±47.46	172.22±71.84	119.23±33.03 ^b	185.93±71.42 ^b
Mean use of	3.86% glucose dialysate	5.92±9.73	4.18±8.72	9.68±8.49 ^c
	icodextrin dialysate	0 (0–31.3)	0 (0–22.7)	2.83±7.54 ^c
Ultrafiltration	22.95±11.41 ^b	12.9±7.58 ^b	21.92±10.61	15.07±8.11
Dialysis adequacy				
Total weekly Kt/V	2.94±0.93	2.42±0.85	2.6±0.67	2.49±1.13
Total weekly CCr (L/1.73 m ²)	85.82±33.41	102.8±48.75	78.79±28.0	101.35±45.26
Biochemical data				
Hemoglobin (g/dL)	9.73±1.72	10.67±1.48 ^b	10.27±1.99 ^c	11.69±1.47 ^{b,c}
Total protein (g/dL)	6.40±1.30	6.79±1.23	6.32±0.75	6.56±0.52
Serum albumin (g/dL)	3.79±0.71	3.66±0.80	3.54±0.48	3.71±0.50
24-Hour proteinuria (mL/kg)	Mean	24.86±43.02	47.66±72.85	16.54±15.00
	Median (range)	15.76 (0–165)	20.7 (0–265)	17.85 (0–33.78)
		21.35 (0–112.4)		

^a $p = 0.06$.^b $p < 0.01$.^c $p < 0.05$.

PD = peritoneal dialysis; CAPD = continuous ambulatory peritoneal dialysis; APD = automated peritoneal dialysis; RRF = residual renal function; GFR = glomerular filtration rate; BSA = body surface area; CCr = creatinine clearance.

within the CAPD and APD groups or between the two groups. Proteinuria was found in 9 children treated with CAPD and in 6 children treated with APD. Median proteinuria did not differ significantly between the groups either at initiation of treatment or at 12 months.

We found a negative correlation between volume of dialysate and duration of treatment in the CAPD group ($r = -0.79$, $p < 0.01$); these two parameters correlated positively in the APD group ($r = 0.89$, $p < 0.0001$). We also found negative correlations between residual diuresis and duration of treatment ($r = -0.9$, $p < 0.0001$), serum albumin level ($r = -0.6$, $p < 0.05$), and volume of dialysate ($r = -0.83$, $p < 0.001$) in the APD group (Figure 1).

Among these 30 children treated with PD, loss of RRF was significantly higher ($p < 0.05$) in patients with chronic pyelonephritis than in patients with primary or secondary glomerulopathy or familial or hereditary renal disease.

Discussion

Better preservation of RRF in patients treated with PD as compared with patients undergoing hemodialysis

has been shown both in adults (9) and in children (7,8). Better preservation of RRF during treatment with PD than with hemodialysis may be explained in several ways. Hemodynamic stability is greater in patients treated with PD (both CAPD and APD) than in patients undergoing hemodialysis, leading to more stable glomerular capillary pressure and therefore more constant glomerular filtration. No studies published in the literature have compared RRF preservation in children treated with CAPD or APD, and only a few such studies have been performed in adult patients. In the latter group, faster RRF loss was reported in patients treated with APD than in those treated with CAPD (12,13), but other authors could not see the effect of the PD modality used (9). In our pediatric patients, better preservation of RRF was demonstrated in the CAPD group than in the APD group.

The mechanism of faster RRF loss in patients treated with APD remains unclear, but it is postulated to be related to the changing volume and osmolality of the dialysate used. In our study population, children treated with APD required larger volumes of dialysate; however, the CAPD group more commonly

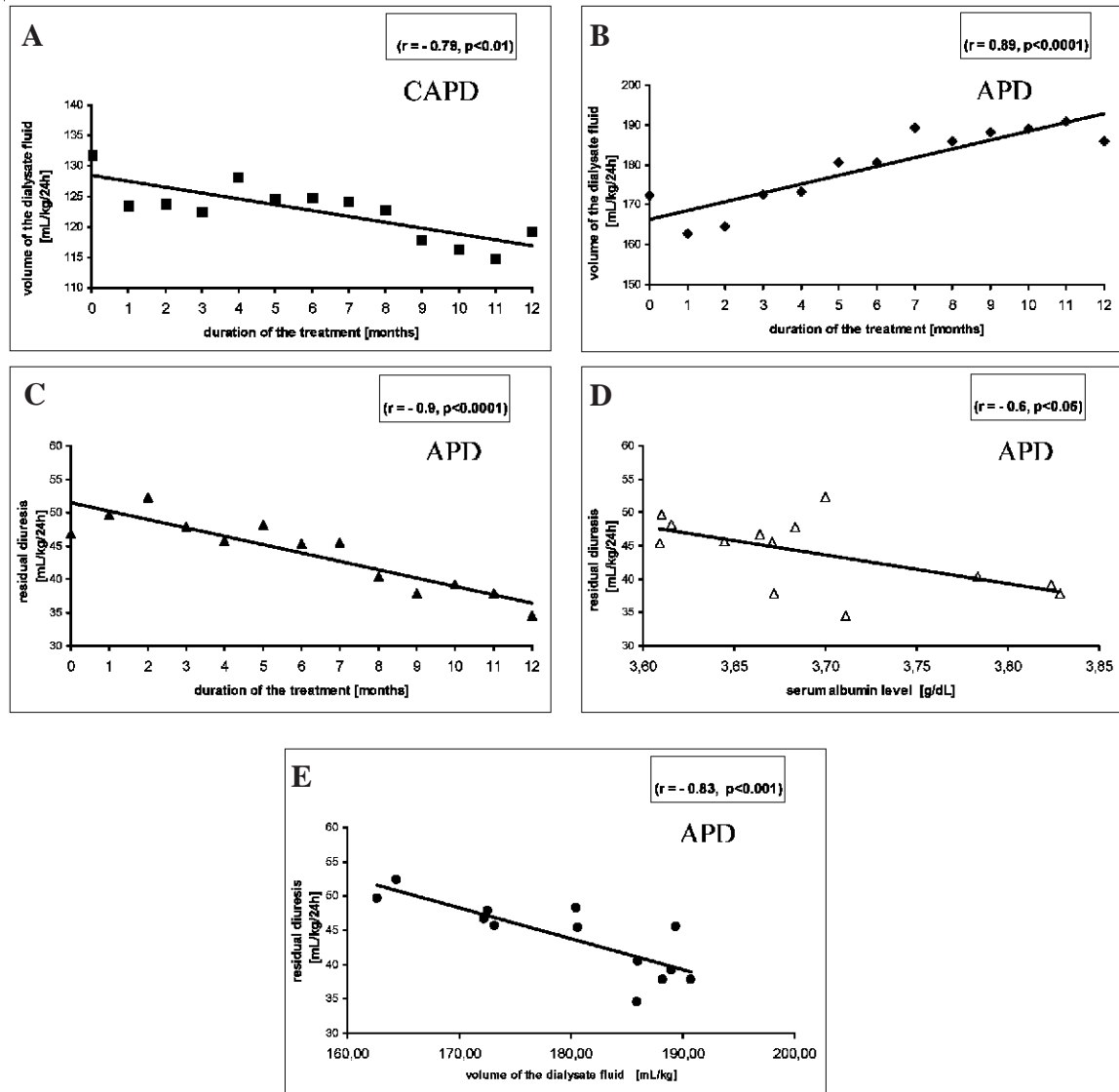


FIGURE 1 Correlations between volume of dialysate and duration of treatment in (A) the continuous ambulatory peritoneal dialysis (CAPD) and (B) automated peritoneal dialysis (APD) groups. Correlations between residual diuresis and (C) duration of treatment, (D) serum albumin, and (E) volume of dialysate in the APD group

used 3.86% glucose dialysate where the APD group used icodextrin fluid. In our children treated with APD, a “wet day” was used in 7 patients. We observed a negative correlation between residual diuresis and the volume of dialysate in the APD group. Some authors have suggested that this faster loss of RRF during APD may slow if fluid remains

in the peritoneal cavity during the day (9). Davies *et al.* were first to report that the use of icodextrin maintains urine output better than conventional dextrose solution only (14). Among our children treated with icodextrin ($n = 4$), stable residual diuresis was found in only 1 patient who was treated with Extraneal for 12 months.

When the effect on RRF of angiotensin converting-enzyme inhibitors was analyzed in a randomized controlled study, it was demonstrated that ramipril may reduce the rate of decline of RRF in adult patients with end-stage renal failure treated with PD (15). Loop diuretics are also known to increase urine volume, but not to affect solute clearance in end-stage adult patients (16). In our children treated with APD, we observed a faster rate of RRF loss despite more frequent use of angiotensin converting-enzyme inhibitors and loop diuretics.

In adult patients with end-stage renal disease secondary to glomerular diseases treated with hemodialysis, RRF loss was more rapid than it was in patients with tubulointerstitial diseases (17). In our pediatric patients treated with PD, we saw better preservation of RRF in children with glomerulopathy.

In children, RRF helps to maintain adequate PD (18). Anuria often precludes PD treatment, and RRF loss requires the use of larger amounts of high glucose dialysate to achieve adequate ultrafiltration, thus promoting peritoneal membrane fibrosis and loss of its dialyzing capability. Reanalysis of data from the CANUSA study (19) and findings from the ADEMEX study (20) demonstrated that RRF has high prognostic value in adult patients.

Conclusions

Our results suggest that RRF seems to be better preserved in children with glomerulopathy or familial or hereditary renal disease, especially in patients treated with CAPD. Further studies in larger groups of patients are needed.

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