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DIALYSIS - TRANSPLANTATION

Clinical application of the Personal Dialysis Capacity (PDC) test: Serial analysis of peritoneal function in CAPD patients

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Clinical application of the Personal Dialysis Capacity (PDC) test: Serial analysis of peritoneal function in CAPD patients.

Background. Peritoneal damage has been reported since the beginning of CAPD therapy.

Methods. To clarify the change of peritoneal function in CAPD patients, we used the Personal Dialysis Capacity (PDC) test in 22 patients with 49 serial studies and 14 patients with single studies. The data were expressed at the condition of 2.5% (2.27 g/dl of glucose), four times at 2,000 ml/day.

Results. In the mass analysis, the urea generation rate, creatinine generation rate, PNA/PCR, and water removal via the peritoneum (PD) were kept at the same level for almost eight years, and then gradually decreased. Urine volume and residual renal creatinine clearance (C_{Cr}) became zero at six years. On the other hand, PD C_{Cr} increased gradually with the time course of CAPD, and therefore the total C_{Cr} remained at the level of 6.0 ml/min even after six years. Weekly urea KT/V decreased gradually from almost 2.800 to 2.000. The protein loss remained approximately 7.0 g/day for the initial five years, then became 6.0 g/day, except in five patients who showed levels above 10.0 g/day on the first test of PDC. Weekly urea KT/V was correlated with residual renal C_{Cr} ($P < 0.005$), and significantly correlated with total C_{Cr} (weekly urea KT/V $= -0.2798 + 0.3720 \times$ total C_{Cr}; $r = 0.915$, $P < 0.001$). In the serial analysis, when the first and the last tests were compared, the urea generation rate increased significantly (mean ± SD, 2.800 ± 3.204 vs. 3.882 ± 3.382; $P < 0.0001$); however, water removal via PD (1364 ± 887 vs. 813 ± 609; $P = 0.021$), total ultrafiltration (1762 ± 841 vs. 1124 ± 843; $P = 0.042$), and weekly urea KT/V (2.285 ± 0.486 vs. 2.112 ± 0.512; $P = 0.026$) decreased significantly. The delta water removal via PD/duration became negative (−10.03 ± 6.59 ml/week) in all 7 patients after more than four years, however, it was positive (+14.40 ± 7.84 ml/week) in 6 of 10 patients after less than one year.

Conclusion. These results suggest that water removal via PD increases within one year, then decreases after four years. The PDC test is useful to evaluate the change of peritoneal function in mass and serial analyses.

Key words: CAPD, peritoneal function, PDC test, equilibrium, urine volume, creatinine clearance, ultrafiltration.

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In 1987, Twardowski et al proposed a peritoneal equilibration test (PET) in order to analyze peritoneal function [1], because peritoneal damage has been reported since the beginning of CAPD therapy. The advantage of PET is that it evaluates the peritoneal condition in each patient, however, it has several problems. One is the need for technical assistance from nurses or medical technicians for the positional change to obtain reasonable data in two hours. Another problem is that the results of PET do not reflect recommendations for practical dialysis treatment, it simply classifies patients into four groups. Finally, there is a lack of digitized data regarding peritoneal function for mass and/or serial analyses.

In 1992, Rippe [2] introduced the "three pore model" to replace the "two pore model," representing the peritoneal membrane for the transport of substances, namely, large pores for protein, small pores for BUN or creatinine, and cell pores for water. Following this concept, Haraldsson [3] developed a computer analysis software program for peritoneal function, and named it the Personal Dialysis Capacity (PDC) test. The useful features of PDC are the convenience of entering data in routine dialysis with two blood samples in 24 hours, the abundant results regarding peritoneal function and diet, the easy recommendation of dialysis treatment for each patient, and the accurate comparison with each digitized datum in both the clinical course of individual patients and mass studies.

We analyzed 49 serial peritoneal function tests of PDC in 22 patients, whose dialysis durations varied from 6 to 22 months, and added a single test of PDC in 14 patients in order to clarify the change of peritoneal function in CAPD patients.

METHODS

Patients

Table 1 shows the characteristics of 22 patients in the serial studies and 14 patients in the single studies.

Table 1. Patients profile and the date of PDC

Patient	Sex	Start	Age	Cause	Outcome	1st PDC	2nd PDC	3rd PDC	4th PDC
TI	F	89.2.20	46.8	CGN	cerebral hemorrhage: alive	95.6.26	96.8.19	97.3.30	
SN	M	89.2.22	41.0	CGN	alive	95.8.28	97.5.30		
AA	F	89.9.29	57.5	CGN	perforation: died	95.7.5	96.4.10		
HI	F	91.5.27	57.3	CGN	SEP: HD: alive	95.9.17	96.8.19		
MK	M	93.8.6	41.9	IgA N	alive	95.8.28	96.6.26	96.11.11	
KM	M	93.12.24	44.3	IgA N	peritoneal failure: HD: alive	95.6.13	96.4.9	96.11.11	97.4.23
KeS	F	92.4.21	41.4	IgA N	alive	95.9.11	96.8.26		
KuS	F	95.6.8	33.1	IgA N	alive	95.6.26	95.12.18		
TA	M	96.1.26	77.4	unknown	alive	96.2.29	97.2.17		
SI	F	96.6.5	22.5	SLE	alive	96.6.25	96.10.15	97.4.2	
SM	M	96.1.18	69.9	DM	cardiomyopathy: died	96.2.26	96.6.19		
KH	M	95.1.18	35.4	unknown	acoustic neurinoma: alive	95.6.6	97.3.10		
YS	M	96.1.9	26.4	unknown	alive	96.2.26	97.3.11		
SS	F	94.1.12	66.8	unknown	alive	96.4.9	97.3.17		
SH	F	94.1.20	54.8	unknown	alive	96.1.16	97.3.17		
YM	F	96.2.19	63.1	amyloid	alive	96.3.18	97.3.24		
MH	M	95.1.25	53.1	unknown	alive	96.2.5	97.2.12		
SO	M	89.7.17	57.5	unknown	SEP: HD: alive	95.9.27	97.5.2		
KeI	F	88.3.1	52.7	IgA N	cerebral hemorrhage: alive	96.4.25	97.6.18		
KT	F	85.9.3	29.8	IgA N	SEP: HD: alive	96.7.10	97.7.17		
MI	M	96.5.4	46.7	unknown	alive	96.5.27	97.6.10		
YH	M	97.1.13	48.3	IgA N	alive	97.2.3	97.4.28		
HA	M	97.4.9	42.6	BMT-N	alive	97.5.9			
KF	M	94.6.7	41.6	IgA N	alive	95.11.6			
KyI	F	86.10.14	39.0	IgA N	alive	97.1.31			
NI	F	91.6.18	43.9	Bartter	alive	96.12.10			
KK	F	96.9.3	64.8	unknown	alive	96.11.6			
HK	F	91.3.20	55.9	unknown	cerebral hemorrhage: died	95.12.5			
MK	F	91.11.5	28.1	pyelo-N	alive	95.8.19			
KyS	F	94.6.23	44.8	SLE	alive	95.9.24			
HS	M	93.1.20	47.6	unknown	alive	97.8.13			
TS	M	86.1.14	31.7	TIN	alive	96.4.11			
US	F	94.5.24	83.5	unknown	alive	95.11.23			
JT	M	95.10.26	56.6	unknown	diverticulitis: HD: alive	95.11.23			
YU	F	94.5.26	65.2	unknown	alive	96.2.3			
MY	F	97.3.28	44.3	IgA N	alive	97.4.24			

Abbreviations are: start, the start of CAPD; age, age at CAPD-start; BMT-N, bone marrow transplant nephropathy; pyelo-N, pyelonephritis; TIN, tubulointerstitial nephritis; SEP, sclerosing encapsulating peritonitis; HD, hemodialysis.

Personal Dialysis Capacity test

The PDC test, provided by Gambro-Shimizu Pharmaceutical company, was used on a version 3.1 system according to the manual by Haraldsson and the laboratory data were entered for each dialysis condition (Baxter Co., Gambro-Shimizu Co, Terumo Co., JMS Co.). The measurement of albumin in dialysate depended on an assay for microalbumin. The expression of PDC data were set at 2.5% (2.27 g/dl of glucose), four times at 2,000 ml/day, because the data from PDC would change due to the different conditions, and could be analyzed by a serial study in each patient and in the mass study. The preliminary study of the concentration of dialysate revealed that 2.27 g/dl is a more adequate level than 1.36 g/dl for serial analysis of peritoneal function, because many patients showed insufficient water removal via the peritoneum (PD) below 1000 ml/day at the concentration of 1.36 g/dl, and some were below 500 ml/day within a few years after the start of CAPD.

The PDC expressed data of peritoneal function included the urea generation rate (mmol/min), creatinine generation rate (mmol/min), protein nitrogen appearance/protein catabolic rate (PNA/PCR in g/24 hr/kg), residual renal function (ml/min/1.73 m^2; residual C_{Cr}), urine volume (ml/day), water removal via PD (ml/dygn), peritoneal dialysis function (ml/min/1.73 m^2; PD C_{Cr}), and weekly urea KT/V including urine, protein loss via PD (g/day), ultrafiltration (ml/day), and total C_{Cr} (ml/min/1.73 m^2; residual renal C_{Cr} + PD Cr).

Water removal

The delta water removal via PD/duration (ml/week) was defined as (the second test − the first test), which was divided by the duration of the first and the second tests (weeks). Positive results indicated an increase of water removal via PD, and negative results indicated a decrease. A high value of delta water removal via PD/duration (ml/week) indicated that the change occurred rapidly.

Table 2. The data of PDC in the serial study

Patient	Year	Urea-g	Cr-g	PNA/PCR	R-C_{Cr}	UV	WR-PD	PD-C_{Cr}	KT/V	S_{alb}	P-loss	Ultra	t-C_{Cr}
TI-1	6.4	0.179	5.0	1.568	0.1	30	2357	6.4	2.152	3.2	6.2	2387	6.5
TI-2	7.5	0.152	5.2	1.391	0.0	0	1798	6.2	2.072	3.6	6.7	1798	6.2
TI-3	8.1	0.159	2.8	1.440	0.0	0	927	5.5	1.905	3.6	2.9	927	5.5
SN-1	6.5	0.131	7.2	1.091	0.5	200	1284	5.5	1.893	2.8	5.6	1484	6.1
SN-1	8.3	0.084	8.4	0.769	0.1	40	329	5.2	1.585	3.2	5.2	369	5.3
AA-1	5.8	0.102	4.0	1.283	0.1	30	1395	5.9	2.282	2.6	7.2	1425	6.0
AA-2	6.6	0.117	4.4	1.418	0.1	30	957	5.5	2.194	2.7	5.9	987	5.7
HI-1	4.3	0.088	3.9	1.205	0.0	0	2269	7.9	2.745	3.1	8.5	2269	7.9
HI-2	5.3	0.078	4.2	1.042	0.0	0	1921	7.0	2.477	3.1	6.4	1921	7.0
MK-1	2.1	0.151	9.1	1.147	0.1	50	2200	5.7	1.711	3.4	9.8	2250	5.8
MK-2	2.9	0.128	7.8	1.044	0.0	0	429	4.8	1.502	3.9	8.5	429	4.8
MK-3	3.3	0.116	9.7	0.993	0.0	0	865	5.2	1.588	3.4	10.3	865	5.2
KM-1	1.5	0.218	10.0	1.551	0.0	0	1826	5.9	1.841	3.4	9.2	1826	5.9
KM-2	2.3	0.198	9.7	1.417	0.0	0	1252	5.5	1.435	3.3	8.0	1252	5.5
KM-3	2.9	0.168	7.3	1.224	0.0	0	948	4.1	1.295	3.9	7.3	948	4.1
KM-4	3.3	0.230	6.7	1.673	0.0	0	−677	4.5	1.418	3.9	6.0	−677	4.5
KeS-1	3.4	0.152	4.6	1.517	0.0	0	939	5.5	1.976	3.5	5.8	939	5.5
KeS-2	4.4	0.141	4.0	1.448	0.0	0	932	6.6	2.202	3.5	6.2	932	6.6
KuS-1	0.0	0.128	6.3	1.273	1.5	200	1180	4.0	2.012	4.1	3.5	1380	5.5
KuS-2	0.5	0.098	6.0	1.004	2.7	360	910	4.3	2.386	3.9	3.0	1270	7.0
TA-1	0.1	−1.175	6.4	−7.448	5.3	1500	1150	4.1	2.958	2.8	12.9	2650	9.4
TA-2	1.1	0.135	6.4	1.371	3.5	1000	2040	7.3	3.324	3.3	9.3	3040	10.8
SI-1	0.1	−0.218	5.4	−0.927	0.7	121	3496	6.7	2.222	3.0	9.7	3617	7.3
SI-2	0.4	0.162	6.9	1.310	0.5	100	3094	5.3	1.966	3.4	5.9	3194	5.8
SI-3	0.8	0.090	5.2	0.817	0.0	0	634	4.3	1.450	3.6	4.1	634	4.3
SM-1	0.1	−0.075	4.6	−0.044	1.1	350	566	5.9	2.088	3.4	11.7	916	7.0
SM-2	0.4	0.185	5.4	1.475	0.3	50	890	6.0	1.795	3.4	19.1	940	6.3
KH-1	0.4	0.087	6.7	0.922	1.9	900	423	5.1	2.221	3.1	7.3	1323	7.0
KH-2	2.1	0.144	7.3	1.249	0.0	0	1228	5.7	1.885	3.9	5.7	1228	5.7
YS-1	0.1	0.063	5.8	0.735	1.5	300	1037	3.2	1.625	3.5	5.7	1337	4.7
YS-2	1.2	0.118	7.2	0.995	0.0	0	1149	5.0	1.624	3.8	5.2	1149	5.0
SS-1	2.2	0.171	5.0	1.273	1.4	300	1999	5.2	1.962	2.9	7.2	2299	6.8
SS-2	3.2	0.147	5.1	1.122	2.5	700	932	5.2	2.090	3.2	8.3	1632	7.7
SH-1	2.0	0.130	4.0	1.225	3.4	1000	1490	5.3	2.815	3.4	6.2	2490	8.8
SH-2	3.2	0.151	5.4	1.432	3.5	1000	601	4.7	2.541	3.6	6.0	1601	8.2
YM-1	0.1	0.107	2.8	1.532	1.5	300	2419	7.3	3.427	3.6	4.7	2719	8.7
YM-2	1.1	0.058	5.0	0.945	3.4	400	564	3.1	2.365	4.0	3.9	964	6.4
MH-1	1.0	0.192	7.3	1.353	3.6	1200	736	4.5	2.372	3.3	5.2	1936	8.0
MH-2	2.1	0.217	9.0	1.482	4.3	1100	590	4.4	2.516	3.7	5.4	1690	8.7
SO-1	6.2	0.048	4.6	0.747	0.0	0	806	5.7	2.054	2.7	5.4	806	5.7
SO-2	7.8	0.066	5.4	0.708	0.0	0	84	5.1	1.603	2.8	4.4	84	5.1
KeI-1	8.2	0.105	5.0	1.009	0.0	0	1232	6.3	1.959	3.1	5.7	1232	6.3
KeI-2	9.3	0.008	4.0	0.829	0.0	0	682	5.8	1.851	3.4	3.5	682	5.8
KT-1	10.9	0.075	4.4	0.898	0.0	0	322	6.2	2.006	3.6	5.8	322	6.2
KT-2	11.9	0.053	3.8	0.740	0.0	0	148	6.2	1.993	3.7	5.8	148	6.2
MI-1	0.1	0.131	6.5	1.204	5.8	1100	−642	4.4	3.144	3.3	12.6	458	10.1
MI-2	1.1	0.175	8.5	1.367	5.5	1000	437	4.7	3.066	3.8	6.0	1437	10.1
YH-1	0.1	0.113	7.1	1.097	4.1	1249	1465	4.6	2.804	3.9	9.3	2714	8.7
YH-2	0.3	0.130	8.5	1.169	2.7	1143	1763	5.8	2.611	2.9	13.0	2906	8.5

Abbreviations are: year, year from the start of CAPD; Urea-g, urea generation rate; Cr-g, creatinine generation rate; PNA/PCR, protein nitrogen appearance/protein catabolic rate; R-C_{Cr}, residual renal creatinine clearance; UV, urine volume; WR-PD, water removal via peritoneal dialysis; PD-C_{Cr}, creatinine clearance of PD; KT/V, weekly urea KT/V (including urine); S_{alb}, serum albumin; P-loss, protein loss via PD; ultra, total ultrafiltration; t-C_{Cr}, total creatinine clearance.

Statistical analysis

Statistical analysis was performed followed by Stat-view on a Macintosh computer. Significant difference for the paired *t*-test (two tail) and regression analysis, was defined as *P* value below 0.05.

RESULTS

Patients

Table 2 shows the 49 serial data, and Table 3 contains the data of single tests in 14 patients.

Changes of parameters from the start of CAPD in a mass analysis

Figure 1 shows the change of urea generation rate, creatinine generation rate, and PNA/PCR. These values increased slightly after one or two years, and then they remained at the same level until almost eight years after the start of CAPD, after which the levels gradually decreased.

Figure 2 shows the water balance. Urine volume became zero after six years. Water removal via the peritoneum differed from patient to patient. Many patients were stable

Table 3. Data of PDC in the single study

Patient	Year	Urea-g	Cr-g	PNA/PCR	R-C_{Cr}	UV	WR-PD	PD-C_{Cr}	KT/V	S_{alb}	P-loss	Ultra	t-C_{Cr}
HA	0.1	0.176	6.9	1.754	5.7	1218	1358	5.4	3.702	4.0	6.0	2576	11.0
KF	1.4	0.106	8.8	0.904	2.7	1000	1716	4.5	2.271	3.9	5.4	2716	7.1
KyI	10.3	−0.056	4.6	−0.092	0.0	0	3378	8.2	2.783	3.3	5.3	3378	8.2
NI	5.5	0.107	3.8	2.073	2.0	800	1265	8.6	4.866	3.8	3.9	2065	10.6
KK	0.2	0.085	3.6	1.867	3.8	500	1681	9.0	5.450	2.6	7.3	2181	12.8
HK	4.7	0.119	5.6	1.060	0.6	400	1614	5.0	1.796	3.4	8.3	2014	5.6
MK	3.8	0.183	5.6	1.688	0.0	0	2550	5.5	2.017	3.7	6.1	2550	5.5
KyS	1.3	0.075	2.4	1.061	1.6	500	1326	5.2	2.614	3.0	4.7	1826	6.8
HS	4.6	0.150	7.6	1.202	1.8	1100	1211	4.4	2.022	3.8	5.7	2311	6.1
TS	10.3	0.096	3.6	1.042	0.0	0	2645	6.9	2.335	3.3	4.8	2645	6.9
US	1.5	0.049	2.3	0.914	0.0	0	2142	6.1	2.366	3.2	6.8	2142	6.1
JT	0.1	0.008	9.7	0.296	4.3	450	1940	3.9	2.319	4.2	6.1	2390	8.2
YU	1.7	0.130	3.8	1.395	2.9	1300	462	5.5	2.794	3.3	8.5	1762	8.3
MY	0.1	0.065	4.4	0.719	2.9	577	1516	4.6	2.424	4.1	4.5	2093	7.4

Abbreviations are: year, year from the start of CAPD; Urea-g, urea generation rate; Cr-g, creatinine generation rate; PNA/PCR, protein nitrogen appearance/protein catabolic rate; R-C_{Cr}, residual renal creatinine clearance; UV, urine volume; WR-PD, water removal via peritoneal dialysis; PD-C_{Cr}, creatinine clearance of PD; KT/V, weekly urea KT/V (including urine); S_{alb}, serum albumin; P-loss, protein loss via PD; ultra, total ultrafiltration; t-C_{Cr}, total creatinine clearance.

for eight years, then the water removal decreased gradually. Ultrafiltration (urine volume + water removal via PD) showed the same pattern as water removal via PD.

Figure 3 demonstrates the time course of residual renal function (residual C_{Cr}), peritoneal dialysis function (PD C_{Cr}), and total C_{Cr} (residual renal C_{Cr} + PD C_{Cr}). The residual renal C_{Cr} slowly decreased and became zero six years after the start of CAPD. On the other hand, PD C_{Cr} increased gradually. The total C_{Cr} remained at the level of 6.0 ml/min even after six years.

Figure 4 shows weekly urea KT/V and the protein loss via the peritoneum. Weekly urea KT/V decreased gradually from almost 2.800 to 2.000. For five years after the start of CAPD, the protein loss remained approximately 7.0 g/day, and then became 6.0 g/day, except for five patients who demonstrated values greater than 10.0 g/day at the first test of PDC. Serum albumin did not relate to other peritoneal function data. There were no significant differences between protein loss and water removal, or between protein loss and total C_{Cr} (data not shown).

Relationship between creatinine clearance and weekly urea KT/V

Figure 5 shows the close relationship between C_{Cr} and weekly urea KT/V. Weekly urea KT/V was correlated with the residual renal C_{Cr} ($P < 0.005$), and was significantly correlated with total C_{Cr} ($Y = -0.2798 + 0.3720X$, where Y is the weekly urea KT/V and X is the total C_{Cr}; $r = 0.915$, $P < 0.001$).

Comparison between the first and the last PDC test in the serial study

We compared the first and the last PDC test data in 22 individual patients. Urea generation rate increased significantly (2.800 ± 3.204 vs. 3.882 ± 3.382, mean ± SD; $P < 0.0001$), however, water removal via PD (1364 ± 887 vs. 813 ± 609; $P = 0.021$), total ultrafiltration (1762 ± 841 vs. 1124 ± 843; $P = 0.042$), and weekly urea KT/V (2.285 ± 0.486 vs. 2.112 ± 0.512; $P = 0.026$) decreased significantly. On the other hand, total C_{Cr} showed no significant differences between the first and the last tests (6.995 ± 1.442 vs. 6.618 ± 1.745, $P = 0.127$). In individual patients, weekly urea KT/V was a better indicator than total C_{Cr} for the change of peritoneal function.

Delta water removal in the serial study

Figure 6 shows that the values for the delta water removal via PD/duration (ml/week) in the serial study were negative in all 7 patients after more than four years. The rates varied from −3.04 to −25.39 ml/week, with the mean value ± SD of −10.03 ± 6.59 ml/week. On the other hand, it was positive in 6 out of 10 patients after less than one year. The rates were between +1.92 and +23.06 ml/week, and the mean value ± SD was +14.41 ± 7.84 ml/week. The negative rates in 4 patients were caused by lupus nephritis, renal amyloidosis, IgA nephropathy, and an unknown cause. These results suggested that water removal via PD increases within one year, and decreases after four years. Regarding patients on CAPD for between one and four years, the water removal varied from −64.80 to +20.54 ml/week, and the mean ± SD was −13.03 ± 26.91 ml/week.

DISCUSSION

The Personal Dialysis Capacity (PDC) test, a computer analysis system to assess peritoneal function, was introduced by Haraldsson [3] in 1995 according to the "three pore model" of Rippe [2]. Few reports regarding the clinical application of PDC have been conducted. We demonstrated the change of peritoneal data from PDC tests in 49 serial studies, of which the duration varied from 6 to 22 months. Individual and mass analysis showed that water removal via PD, weekly urea KT/V, and total ultrafiltration decreased significantly with the time course of CAPD. In particular, water removal via PD decreased after

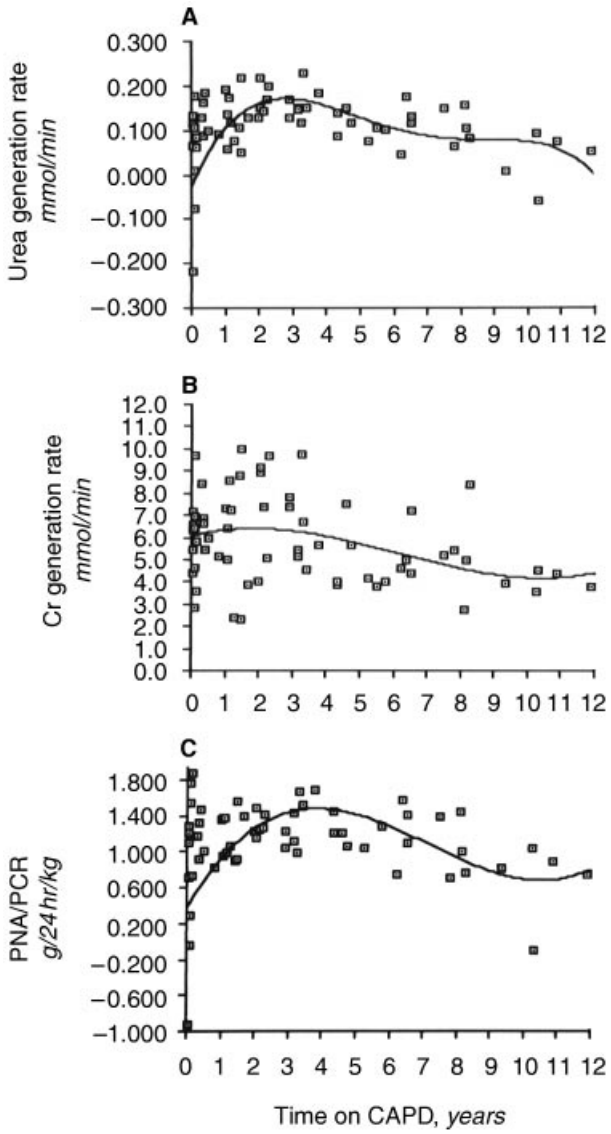

Fig. 1. (*A*) Change in the urea generation rate. $-0.0281 + 0.1784X - 0.0523X^2 + 0.0056X^3 - 0.00026X^4$ ($r = 0.368$). (*B*) Change in the creatinine generation rate was: $0.4172X - 0.1312X^2 + 0.00711X^3$ ($r = 0.351$). (*C*) The change of PNA/PCR was: $0.6525X - 0.1157X^2 + 0.00537X^3$ ($r = 0.320$).

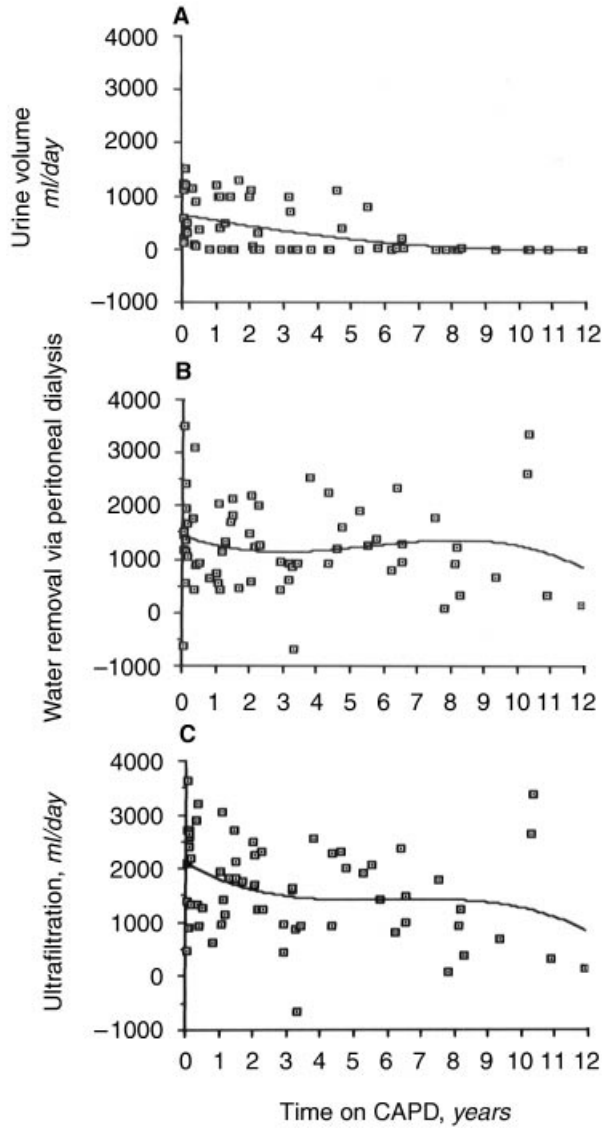

Fig. 2. Water balance. (*A*) Change in the urine volume over time. The urine volume became zero after six years. (*B*) Peritoneum (PD) removal decreased to below 1000 ml/day after eight years, except in two patients. (*C*) The change of total ultrafiltration. Note that the pattern is same as in B.

four years; however, the total water balance remained stable for eight years, since urine volume was maintained for six years. After that time, the loss of ultrafiltration would be a serious problem. The serial data support the idea that the conclusion of mass analysis is valid, but for a much shorter time interval. Thus, it is necessary to find a suitable method to protect the peritoneum, and to prolong the stable period.

Several reports have already pointed out the decrease of ultrafiltration in long-term CAPD patients. In 1990, Heimbuerger et al reported that 14 of 227 patients (6.2%) were transferred from CAPD to hemodialysis (HD) due to the loss of ultrafiltration after 10 years, and 2.6% after one year, 9.5% after three years, and 30.9% after six years [4]. In 1994, Selgas et al demonstrated the change of peritoneal function by the quantification of peritoneal mass transfer coefficients (MTCs), and found that the ultrafiltration decreased significantly after four to eight years (1800 ± 530, 1400 ± 600 ml/day, respectively, $P < 0.01$) [5]. Although 5 of 56 patients (8.9%) were transferred from CAPD to HD, the other patients did not have problems with CAPD therapy. Davies et al also pointed out that the solute transfer increases and the ultrafiltration decreases with the time course of CAPD, and peritonitis aggravates these changes [6]. Struijk et al analyzed the change of peritoneal function prospectively, and demonstrated the

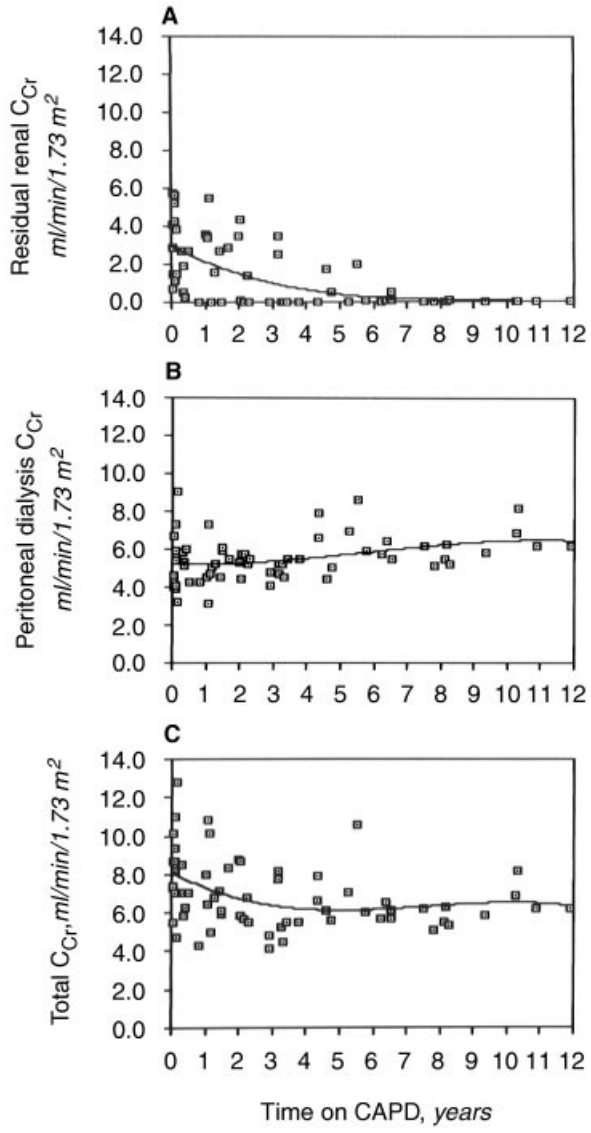

Fig. 3. Creatinine clearance (C_{Cr}). (*A*) The change of residual renal C_{Cr}: $0.9281X + 0.1023X^2 - 0.00328X^3$ ($r = 0.603$). (*B*) The change of peritoneum (PD) C_{Cr}: $0.0316X + 0.0378X^2 - 0.00219X^3$ ($r = 0.366$). (*C*) The change of total C_{Cr}: $Y = 8.1272 - 0.9466X + 0.1390X^2 - 0.00604X^3$ ($r = 0.403$).

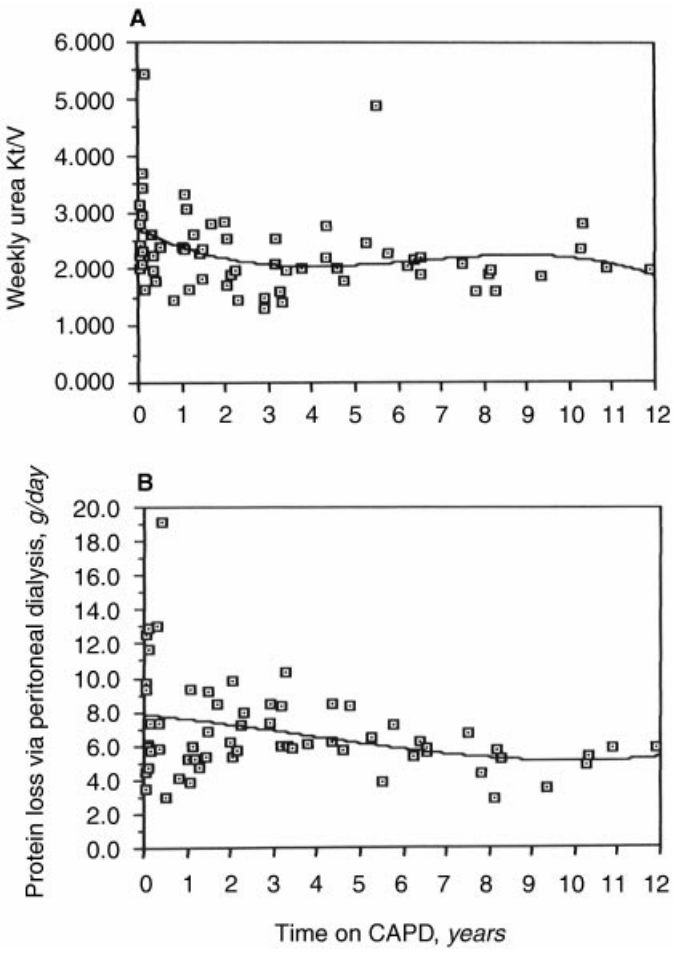

Fig. 4. (*A*) The change of weekly urea KT/V. $0.3801X + 0.0682X^2 - 0.00352X^3$ ($r = 0.318$). (*B*) The change of protein loss via the peritoneum (PD). $0.2463X - 0.0342X^2 + 0.00309X^3$ ($r = 0.346$).

increase of net ultrafiltration and the decrease of glucose absorption after 1.5 years from the start of CAPD [7]. The present study reveals that ultrafiltration after more than four years decreased at the rate of -10.03 ± 6.59 ml/week, which is in agreement with the reports of Heimbuerger et al and Selgas et al [4, 5]. Our study also demonstrated that the ultrafiltration of 6 patients in the initial phase of CAPD of less than one year increased at the rate of $+14.41 \pm 7.84$ ml/week, in agreement compatible with the data of Struijk et al [7]. However, the patients suffering from lupus nephritis and amyloidosis in our study showed a rapid decrease of ultrafiltration. Three (patients HI, SO and KT) of 7 patients (43%) with long-term CAPD were transferred from CAPD to hemodialysis due to sclerosing encapsulating peritonitis (patient SEP) after the second test of PDC, and patient KM was also transferred to HD due to the loss of ultrafiltration. Heimbuerger et al speculated that the cause of the loss of ultrafiltration depends on the osmotic driving force due to increased diffusive mass transport for small solutes and/or the increased fluid reabsorption due to increased lymphatic resorption [4]. Why the water removal via PD would increase in the initial phase of CAPD is unknown. This phenomenon is thought to be unfavorable for the water balance, since the urine volume is still maintained at this phase. We should pay attention to the initial stage with residual renal function, and a lower glucose concentration of dialysate and/or lower osmotic dialysate should be used to maintain the peritoneal function. Further study using PDC will clarify the mechanism of the loss of ultrafiltration and help determine a protective method against the decrease of ultrafiltration. PDC shows that peritoneal function changes with the time course of CAPD.

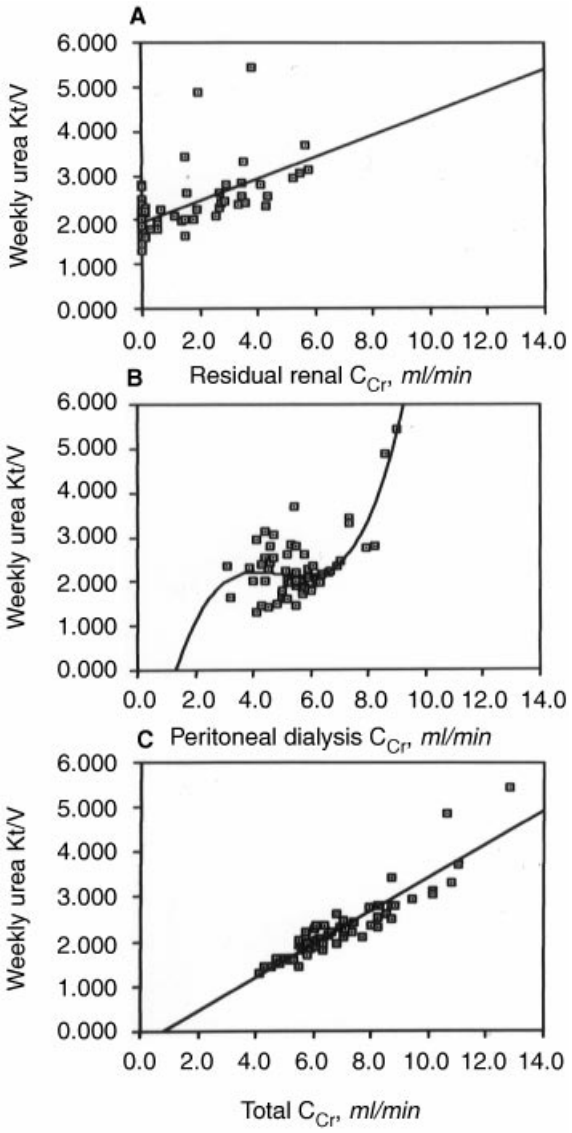

Fig. 5. The relationship between weekly urea KT/V and creatinine clearance (C_{Cr}). (*A*) The relationship between weekly urea KT/V and residual renal C_{Cr}. $1.9431 + 0.2495X$ ($r = 0.60$). (*B*) The relationship between weekly urea KT/V and PD C_{Cr}. $-3.8562 + 3.8687X - 0.8056X^2 + 0.0544X^3$ ($r = 0.75$). (*C*) The relationship between weekly urea KT/V and total C_{Cr}. $-0.2798 + 0.3720X$ ($r = 0.915$).

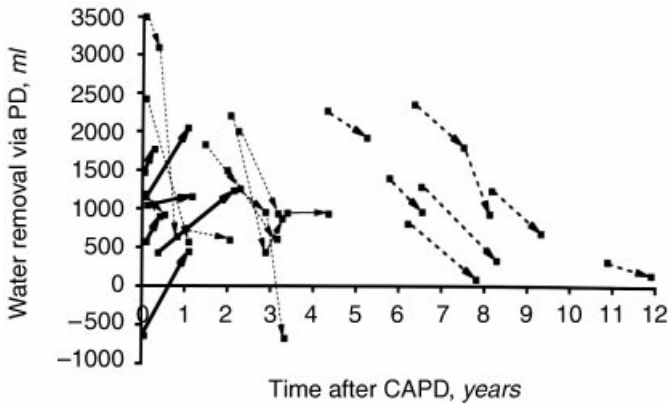

Fig. 6. The change of water removal via the peritoneum (PD) in the serial analysis. The water removal via PD decreased in seven patients after more than four years. Their rates varied from −3.04 to −25.39 ml/week, and the mean value ± SD was −10.03 ± 6.59 ml/week. In 6 of 10 patients after less than one year, the rates were between +1.92 and +23.06 ml/week, and the mean value ± SD was +14.41 ± 7.84 ml/week. The decreased water removal via PD in four patients were caused by lupus nephritis, renal amyloidosis, IgA nephropathy, and an unknown cause.

Urea and creatinine are transported from the circulation into the peritoneal cavity via small pores in the vascular wall. To evaluate dialysis effectiveness, weekly urea KT/V and C_{Cr} measurements have been generally used: The CANUSA study group used the former [8], while the Scandinavian group using PDC indicated C_{Cr}. The present study revealed a significant correlation between weekly urea KT/V and total C_{Cr}. Keshaviah [9] reported the same relationship, and Vonesh et al [10] evaluated this relationship using PD ADEQUEST introduced by Baxter Co. They expressed the relationship as follows: weekly urea KT/V = $0.595 + 0.025 \times C_{Cr}$ ($r = 0.82, P < 0.0001$). Our results are: weekly urea KT/V = $-0.2798 + 0.3720 \times C_{Cr}$ ($r = 0.915$, $P < 0.001$). Even though the mathematical formulae differ, a close relationship between C_{Cr} and weekly urea KT/V was proven in both studies. The value of weekly urea KT/V is more accurate than C_{Cr}, when we compare the serial data in individual cases, because PD C_{Cr} increases, but weekly urea KT/V decreases gradually with the time couse of CAPD. Therefore, it was reasonable for the CANUSA study group to use weekly KT/V as a marker of dialysis and/or peritoneal condition. The present study revealed that PNA/PCR values greater than 1.10, indicating an excessive intake of protein, were found in 28 out of 49 serial studies (57%). Those patients are targeted to receive further education about the importance of maintaining an adequate diet to prevent dialysis overloading.

In conclusion, PDC is an excellent and promising tool to evaluate the peritoneal function in serial analyses of individual patients and also mass analyses of CAPD patients, because the data are expressed as digital numbers. Further studies including a larger number of patients will provide accurate data of peritoneal function, and these data will help to develop a useful method to maintain a stable peritoneal function in CAPD patients.

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APPENDIX

Abbreviations used in this article are: CAPD, continuous ambulatory peritoneal dialysis; C_{Cr}, creatinine clearance; HD, hemodialysis; MTC, mass transfer coefficient; PD, peritoneum; PDC, Personal Dialysis Capacity; PD C_{Cr}, peritoneal dialysis function; PET, peritoneal equilibration test; PNA/PCR, protein nitrogen appearance/protein catabolic rate; residual C_{Cr}, residual renal function.

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