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□원 저□

Outcomes of Chronic Peritoneal Dialysis by Various Modalities in Korean Children - A Single Center Study

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= **Abstract** =

Purpose : A single center cross sectional retrospective study was performed to compare the outcomes of different peritoneal dialysis(PD) modalities in Korean children.

Methods : Among children dialyzed with PD between the year 2004 and 2007, 35 children had reliable data on PD adequacy after 3 to 15 months of dialysis. Subjects were grouped by their modalities; 17, 13 and 5 children were on continuous ambulatory PD(CAPD), continuous cyclic PD(CCPD) and nightly intermittent PD(NIPD), respectively. Body weight and height, number of patients taking anti-hypertensives and laboratory data including biochemical and hemoglobin levels were compared. Dialysis adequacy including weekly Kt/Vurea, creatinine clearance (Ccr) and daily water removal were also compared. Patients were sub-grouped by their peritoneal permeability characteristics.

Results : The percentage of patients taking anti-hypertensives, monthly change in Z-scores of body weight and height and laboratory data did not differ among the groups. Patients on CAPD and CCPD showed similar dialysis adequacies. Weekly dialytic Ccr was significantly lower in the NIPD group compared to the others. But total Ccr was not different when residual renal function was added. Weekly dialytic Ccr by CAPD was significantly higher than that of CCPD in low and low-average transporters.

Conclusion : We propose that modality can be selected flexibly according to the patients' preferences. And peritoneal permeability characteristics provide valuable information for adjusting PD prescriptions in ultrafiltration failure or in inadequate dialysis. Further study of other clinical performance measures should be performed to clarify the comparable outcomes in different PD modalities. **(J Korean Soc Pediatr Nephrol 2007;11:255-263)**

Key Words : Chronic peritoneal dialysis, Continuous ambulatory peritoneal dialysis, Automated peritoneal dialysis, Continuous cyclic peritoneal dialysis, Nightly intermittent peritoneal dialysis, Dialysis adequacy

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INTRODUCTION

There has been a worldwide increase in the use of automated peritoneal dialysis(APD) in

children especially in developed countries[1-6]. Among children dialyzed with chronic peritoneal dialysis(CPD) in our center, the percentage of APD population has also increased from 19% in 2002 to 45% in 2006. The preference for APD in children is in large part because it allows uninterrupted daytime activities[3, 6]. Another reason is that the short cycles of APD is believed to fit better with the characteristics of peritoneal membrane transport in children[7-9]. However, there is only one clinical report comparing outcomes of CAPD and CCPD in children, and it reports superior outcomes with CCPD compared CAPD[10]. But there has been controversies in adults dealing with the issue[11-16]. Moreover, there are only few reports on clinical outcomes of Korean children dialyzed with CPD[17-19], and none comparing them between different modalities. We performed a single center cross sectional retrospective study to compare the outcomes of different PD modalities in Korean children.

MATERIALS AND METHODS

Among the children who have been dialyzed with CPD from the year 2004 to 2007, 35 patients(21 boys and 14 girls) had reliable data of PD adequacy measures between 3 months and 15 months after dialysis initiation. Their mean age was 11.3±5.1 years and mean duration of dialysis was 8.5±2.9 months. The patients were divided into three groups according to their CPD modalities at the time of enrollment. Selection of PD modality has been influenced mostly by preferences of the patients or their parents in our center. Seventeen(49%), 13(37%), and 5(14%) patients were grouped into continuous ambulatory PD(CAPD), continuous cyclic PD(CCPD) and nightly intermittent PD (NIPD) groups, respectively.

The patients' medical records were reviewed retrospectively. The anthropometric data including body weight(Bwt) and height(Ht) at the time of dialysis initiation and at the time of adequacy evaluation(from 3 to 15 months after dialysis) were collected. Z-scores of Bwt and Ht were calculated from standard growth value in Korean children[20], and monthly changes in the Z-scores were analyzed. PD prescription including night time fill volume, total daily cycles and total daily dialysate volume were reviewed. The number of patients taking antihypertensive medication in each group were also investigated. Biochemical data(serum albumin, calcium, phosphorus, intact parathyroid hormone, alkaline phosphatase), and serum hemoglobin levels were gathered.

PD adequacy was measured by calculating total, peritoneal, and residual renal weekly Kt/V_{urea}, as well as total, peritoneal, and residual renal weekly creatinine clearance(Ccr). Daily peritoneal ultrafiltration volume(UFV), and urine volume(UV) were measured and were summed to calculate total daily water removal.

Peritoneal equilibration test(PET) was performed after an initial dwell of 2.5% dextrose solution for more than 4 hours in the morning. The initial solution was drained for 20 minutes before the PET. Dextrose solution(2.5%, 1,000-1,100 mL/m^2) was infused as the test solution over 10 minutes with the patient rolling from side to side every 1 to 2 minutes during the infusion. Dialysate samples were taken at 0, 1, 2 and 4 hours of dwell time. At 0, 1 and 2 hours of dwell time, 10 percent of initial fill volume

was drained into collection bag and after mixing well, 3 mL was removed for analysis. The remaining was reinfused back to the patient. At 4 hours of dwell time, the test solution was drained completely over 20 minutes at sitting position. After mixing well, 3 mL was removed for analysis. A blood sample for serum glucose, sodium, urea and creatinine was taken at 2 hours of dwell time. PET was interpreted according to the cut-off values presented by B. Warady[8]. The values for PET results were expressed as high, high average, low average or low transporters.

Results were expressed as mean±standard deviation. Statistical analysis was performed by the SPSS 12.0K statistical package. Chi-square test and Mann-Whitney U test were performed to compare binary and continuous variables, respectively.

RESULTS

1. Patient characteristics

The demographic features of the patients in each group are summarized in Table 1. There were no differences in gender distribution, age at enrollment and duration of PD between the groups.

2. PD prescription

The PD prescriptions are summarized in Table 2. The NIPD group received less amount of night-time fill volume per cycle than the CCPD group(890±116 mL/m^2/cycle in NIPD and 1013±83 mL/m^2/cycle in CCPD group; P=0.04). Total dialysis cycles and daily dialysate volume delivered by APD(CCPD and NIPD) groups were higher than that of the CAPD group. All patients received adequate fill volumes of less than 1400 mL/m^2, as recommened by recent guidelines[21, 22].

3. Number of patients taking anti-hypertensives, monthly changes in Z-scores of Bwt and Ht, biochemical and hematologic data

There was no significant difference in the proportion of patients receiving anti-hypertensives between the groups; 47% in CAPD, 62%

Table 1. Demographic Features of the Patients

	CAPD(n=17)	CCPD(n=13)	NIPD(n=5)
M:F	12:5	5:8	4:1
Age at enrollment(years)	12.08±4.75	11.34±5.24	8.40±5.77
PD Duration(months)	8.06±3.34	8.77±2.77	9.20±2.05

P>0.05 in all comparisons

Table 2. Night-time Fill Volume and Number of Daily Cycles

	CAPD(n=17)	CCPD(n=13)	NIPD(n=5)
Night-time Fill volume(mL/m^2/cycle)	969±153	1,013±83	890±116*
Total Daily Cycles(doses/day)	4.00±0.35†	6.53±0.87	6.40±2.07
Total Daily Dialysate Volume(mL/m^2/day)	3,885±856†	6,216±795	5,613±1,444

*P=0.04 vs CCPD, †P=0.00 vs CCPD and 0.00 vs NIPD, ‡P=0.00 vs CCPD and 0.25 vs NIPD

in CCPD and 40% in NIPD group. Monthly changes in Z-scores of Bwt and Ht during the study period were not different between the groups either. There were no differences in levels of serum calcium, phosphorus, intact parathyroid hormone and alkaline phosphatase between the groups. The serum albumin level of the CCPD group was significantly lower than the CAPD group(3.88±0.29 in CCPD group and 4.08±0.21 in CAPD group; P=0.04). But all the values were above lower normal limit of 3.5 g/dL. There were no differences in serum hemoglobin levels between the groups (Table 3).

4. Peritoneal Dialysis Adequacy and Daily Water Removal

PD adequacy measures and daily water removal are summarized in Table 4. There were no differences in total Kt/V_{urea}, Kt/V_{urea} by PD and Kt/V_{urea} by residual renal function(RRF) between the groups. Twenty seven children(77 %) met the recommended minimal Kt/V_{urea} of 1.8 by K/DOQI recommendations[22]; 14 children

Table 3. Patients Taking Anti-hypertensives, Changes in z-score of Body Weight and Height, Biochemical and Hematologic Data

	CAPD(n=17)	CCPD(n=13)	NIPD(n=5)
Percent of patients on anti-hypertensives	47%	62%	40%
Change in z-score of weight(per month)	-0.01±0.11	0.02±0.11	0.04±0.07
Change in z-score of hight(per month)	-0.01±0.06	-0.04±0.21	0.04±0.03
Albumin(g/dL)	4.08±0.21	3.88±0.29*	3.68±0.61
Calcium(mg/dL)	9.67±1.19	9.71±0.80	9.86±0.34
Phosphorus(mg/dL)	4.52±0.19	4.96±0.93	5.22±0.42
Intact PTH(pg/mL)	166±196	179±164	278±410
Alkaline phosphatase(IU/L)	263±135	253±121	472±345
Hemoglobin(g/dL)	11.51±1.44	10.72±1.66	10.38±1.78

*P=0.04 vs CAPD, but all were above 3.5 g/dL. P>0.05 in all the other comparisons

Table 4. PD Adequacy and Water Removal Achieved by Different Dialysis Modalities

	CAPD(n=17)	CCPD(n=13)	NIPD(n=5)
Weekly Kt/V_{urea}			
Total(PD+Renal)	2.17±0.42	2.16±0.57	2.30±0.45
PD	1.67±0.47	1.61±0.64	1.70±0.57
Renal	0.50±0.56	0.49±0.49	0.61±0.62
Total Weekly Ccr(L/week/1.73m^2)			
Total(PD+Renal)	51.3±15.1	46.8±12.8	40.9±11.3
PD	34.4±6.7	33.1±7.1	22.4±7.06†
Renal	17.0±19.0	13.7±13.5	18.6±17.2
Daily Water Removal(mL/m^2/day)			
Total(PD+Renal)	1,120±368	878±207	1,162±382
PD	664±402	611±177	414±211
Renal	457±524	267±276	748±557

Paired variables were analyzed by Mann-Whitney U test, †P=0.03 vs CAPD and 0.01 vs CCPD, P>0.05 in all the other comparisons

(82%) on CAPD, 9 children(69%) on CCPD and 4 children(80%) on NIPD.

Weekly Ccr by PD was significantly lower in the NIPD group compared to the CAPD and CCPD group(P=0.03 and 0.01, respectively). However, when residual renal Ccr was added to Ccr by PD, there were no differences in total Ccr between the groups. Differences in residual renal Ccr between the groups were not significant.

Daily peritoneal ultrafiltration volume(UFV), urine volume(UV) and total daily water removal were not different between the groups.

5. Solute and water removal in sub-groups of different peritoneal permeability

Reliable data on PET were available in only a limited number of patients. The patients were sub-grouped by their peritoneal permeability characteristics according to their 4 hour D/P creatinine and D/Do glucose results. For the comparison of solute removal including Kt/V_{urea} and Ccr, patients were subgrouped by D/P creatinine ratio, whereas D/D0 glucose ratio was applied for the comparison of water removal.

The PD adequacy and daily ultrafiltration volume in sub-groups of different peritoneal permeability are summarized in Table 5. Among low and low-average transporters, 7 were on CAPD, 7 were on CCPD and 2 were on NIPD. In this group, CAPD seemed to have achieved better weekly dialytic Kt/V_{urea}, Ccr and UFV than CCPD. But statistical significance was identified only in weekly dialytic Ccr due to the small number of patients(P=0.04). Among high and high-average transporters, 3 were on CAPD, 4 were on CCPD and 1 was on NIPD. Though statistical analysis was not possible because of the small number of patients in this group, the differences between the means were much less compared to those in the low and low average transporters.

Total solute and water removal in sub-groups of different peritoneal permeability are summarized in Table 6. Total weekly Kt/V_{urea}, Ccr and daily water removal achieved by the three modalities did not differ significantly regardless

Table 5. PD Adequacy and Ultrafiltration Volume in Sub-groups of Different Peritoneal Permeabilities

	CAPD	CCPD	NIPD
Weekly Kt/Vurea by PD			
Low/Low-average Transporters	1.80±0.30(n=7)	1.63±0.41(n=7)	2.01±0.94(n=2)
High/High-average Transporters (according to 4hr D/P Cr)	1.58±0.18(n=3)	1.95±0.51(n=4)	1.46±0.00(n=1)
Weekly Ccr by PD			
Low/Low-average Transporters	38.5±4.7*(n=7)	31.7±7.7(n=7)	21.5±9.8(n=2)
High/High-average Transporters (according to 4hr D/P Cr)	37.4±6.2(n=3)	32.5±7.1(n=4)	20.4±0.0(n=1)
Daily Ultrafiltration Volume			
Low/Low-average Transporters	706±356(n=9)	654±197(n=7)	548±312(n=2)
High/High-average Transporters (according to 4hr D/Do Glu)	655±0(n=1)	500±133(n=4)	277±0(n=1)

*P=0.04 vs CCPD

Table 6. Total Solute Removal and Water Removal in Sub-groups of Different Peritoneal Permeabilities

	CAPD	CCPD	NIPD
Total Weekly Kt/Vurea			
Low/Low-average Transporters	2.16±4.11(n=7)	2.00±0.39(n=7)	2.73±0.07(n=2)
High/High-average Transporters) (according to 4hr D/P Cr)	1.83±0.38(n=3)	2.20±0.33(n=4)	2.20±0.00(n=1)
Total Weekly Ccr			
Low/Low-average Transporters	50.0±11.1(n=7)	46.3±15.3(n=7)	43.7±21.7(n=2)
High/High-average Transporters (according to 4hr D/P Cr)	44.8±7.9(n=3)	43.6±2.2(n=4)	41.6±0.0(n=1)
Total Daily Water Removal			
Low/Low-average Transporters	1,083±329(n=10)	896±261(n=8)	1,023±613(n=2)
High/High-average Transporters (according to 4hr D/Do Glu)	655±0(n=1)	812±83(n=4)	1,236±0(n=1)

of their peritoneal permeability characteristics.

DISCUSSION

The introduction of automated PD technologies has provided diversity in the prescription of PD. It has been perceived that APD has the potential to deliver more clearance than CAPD not only in adults[11], but also in children[7-9]. However, there has been controversies in clinical experiences considering the issue. Some investigators[11-13], in adult patients, observed that CCPD was better than CAPD in ultrafiltration and urea clearance. Another investigator also reported similar outcomes in children[10]. On the contrary, others failed to demonstrate statistically significant differences in adequacy of dialysis between the modalities[14-16]. Since there have been no reports concerning the distinct outcomes of various PD modalities in Korean children, a retrospective study was undertaken to disclose the issue.

Though APD has become more popular recently, a comparable number of patients were still on CAPD during the study period. Unfamiliarity of APD as well as higher cost for APD can be possible reasons for the high percentage of our patients on CAPD. The night-time fill volume was significantly lower in the NIPD compared to the CCPD group because it was prescribed only to those with substantial residual renal function, as recommended by recent guidelines[21, 22]. As expected by the characteristics of APD, daily cycles and total dialysate volume delivered were greater in the APD(NIPD and CCPD) group compared to the CAPD group.

The percentage of patients on anti-hypertensives did not differ between the groups, and most of them were treated with one or two medications. Although a monthly change in Z-scores of body weight and height did not differ between the groups, further study based on long-term observation should be carried out to clarify the effect of PD modality on the growth of the patients. Serum hemoglobin and biochemical values were not different between the groups. Most of the patients were treated with phosphate binders and erythropoietin.

Our study, as had others[14-16], could not demonstrate statistically significant differences

in the adequacy of dialysis as determined by weekly dialytic Kt/V_{urea} and weekly dialytic Ccr between CAPD and CCPD. The reason seems to be clear for CCPD patients. The dialysate and plasma solute concentrations do not reach equilibrium due to the shorter dwell time in CCPD compared to CAPD[23-25]. In addition, the ultrafiltration volume was similar in both groups despite the CCPD group having a higher total dialysate volume compared to the CAPD group. Shorter dwell time, thus less time offered for ultrafiltration can also account for the observation.

NIPD has disadvantages in the clearance of middle-sized molecules and ultrafiltration[23-25]. Our study also demonstrated significantly lower weekly dialytic Ccr in the NIPD group. But significant residual renal function in this group overcame the disadvantage.

It is perceived that in low transporters, APD will frequently lead to lower clearances than CAPD because these patients depend on dwell-time for clearance. On the other hand, APD has its advantage over CAPD in high transporters [22, 24]. Although comparing outcomes in sub-groups of different peritoneal characters was limited due to the small numbers of the patients, our study demonstrated better outcomes with CAPD than CCPD among low or low-average transporters in one correlation; weekly dialytic Ccr by CAPD was significantly higher than that of CCPD. But when solute and water clearances by residual renal function was added, total weekly Kt/V_{urea}, Ccr and daily water removal achieved by three modalities did not differ significantly regardless of their peritoneal permeability characteristics.

All the outcome measures evaluated in this study were not different between CAPD, CCPD and NIPD groups. And NIPD achieved acceptable clearances of solute and water removal in those with substantial residual renal function. Thus, we propose that the modality can be selected flexibly according to the patients' or parents' preferences rather than being strictly predetermined by individual peritoneal permeability characteristics. However, PET provides valuable information for adjusting PD prescriptions in ultrafiltration failure or in inadequate dialysis. Further study on additional clinical performance measures including long-term growth, nutritional status and peritonitis rate should be carried out to clarify the comparable outcomes in different PD modalities.

한 글 요 약

목 적 : 단일 기관에서 만성복막투석을 시행 받고 있는 소아 환자를 대상으로 후향적 단면연구를 시행하여 복막투석 방법에 따른 투석 결과의 차이가 있는지에 대하여 연구해 보고자 한다.

방 법 : 단일 기관에서 2004년과 2007년 사이에 복막투석을 시행 받았던 환자들 중 투석 후 3개월에서 15개월 사이에 복막투석 적절도에 대한 평가가 이루어졌던 35명의 환자를 대상으로 하였다. 연구 당시 시행하고 있던 복막투석 방법에 따라 CAPD 군, CCPD 군과 NIPD 군으로 환자들을 분류하였고 각각 17명, 13명, 5명의 환자들이 포함되었다. 각 군 사이에 항고혈압제를 복용하고 있는 환자 수, 체중, 신장 및 일반화학 검사와 혈색소 검사를 포함한 혈액 검사 결과의 차이가 있는지 비교 분석하였다. 투석 및 잔여 신기능을 통한 주간 Kt/V_{urea}, Ccr과 초여과양 및 소변량에 대한 비교 분석도 시행하였다. 표준 방법을 통한 복막평형검사를 시행하여 개인의 복막 투과성에 대해서도 알아보았다.

결 과 : 각 군 간에 항고혈압제를 복용하고 있는 환자의 비율, 체중과 신장 Z-score의 월간 변화 및 혈액검사 평균 수치의 차이는 유의하지 않았다. CAPD 군과 CCPD 군에서, 복막투석 및 잔여 신기능을 통한 주간 Kt/Vurea, Ccr 및 수분 배설 의 차이는 없었다. NIPD 군의 복막투석을 통한 주간 Ccr이 다른 두 군에서보다 유의하게 낮았지만, 잔여 신기능을 통한 보상으로 총 주간 Ccr에는 차이가 없었다. 복막 평형 검사 결과 저 투과성(low transporter) 및 저 평균 투과성(low-average transporter)으로 분류되었던 환자들을 대상으로 비교하였을 때, CAPD를 통한 주간 Ccr이 CCPD를 통한 주간 Ccr 보다 유의하게 높았다.

결 론 : 본 연구의 결과를 토대로, 소아 만성복막투석 환자들에 있어서 투석 방법은 환자의 선호도에 의하여 자유롭게 선택될 수 있어야 할 것을 제안하는 바이다. 또한 초여과의 실패 및 부적절한 투석으로 투석 방법의 변경이 불가피한 상황에서, 복막 평형 검사는 투석 방법 변경이 적절이 이루어질 수 있도록 도와주는 귀중한 정보를 제공해 줄 것이다. 투석 방법 간의 명확한 비교를 위하여 향후 복막염의 빈도, 영양상태 및 장기간의 성장 등 다양한 투석 성적을 비교하는 추가 연구가 필요할 것으로 생각된다.

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