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Cycler adequacy and prescription data in a national cohort sample: The 1997 core indicators report

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Background. The Health Care Financing Administration Peritoneal Dialysis Core Indicator Project obtains data yearly in four areas of patient care: dialysis adequacy, anemia, blood pressure, and nutrition.

Methods. Adequacy and dialysis prescription data were obtained using a standardized data abstraction form from a random sample of adult U.S. peritoneal dialysis patients who were alive on December 31, 1996.

Results. For the cohort receiving cycler dialysis, 22% were unable to meet the National Kidney Foundation Dialysis Outcome Quality Initiatives (NKF-DOQI) dialysis adequacy guidelines because they did not have at least one adequacy measure during the six-month period of observation. Thirty-six percent of patients met NKF-DOQI guidelines for weekly Kt/V urea, 33% met guidelines for weekly creatinine clearance (C_{Cr}), and 24% met guidelines for both urea and creatinine clearances. The mean weekly adequacy values were 2.24 ± 0.56 for Kt/V urea and 67.5 ± 24.4 liter/1.73 m^2 for C_{Cr}, and the median values were 2.20 and 62.25 liter/1.73 m^2, respectively. The mean prescribed 24-hour volume was 12,040 ± 3255 ml, and the median prescribed volume was 11,783 ml. Only 60% of patients were prescribed at least one daytime dwell. By logistic regression analysis, risk factors for an inadequate dose of dialysis included being in the highest quartile of body surface area (odds ratio = 3.3 for C_{Cr} and 3.4 for Kt/V urea) and a duration of dialysis greater than two years (odds ratio = 4.2 for C_{Cr} and 2.1 for Kt/V urea).

Conclusion. There is much room for improvement in providing an adequate dose of dialysis to cycler patients. Practitioners should be more aggressive in increasing dwell volumes, adding daytime dwells, and adjusting nighttime dwell times in order to compensate for the loss of residual renal function over time. These changes can only be accomplished if practitioners measure periodically the dose of dialysis as outlined in the NKF-DOQI guidelines.

Key words: cycler dialysis, peritoneal dialysis, Kt/V urea, creatinine clearance, dialysis adequacy, NKF-DOQI guidelines.

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Peritoneal dialysis (PD) remains a small but important renal replacement modality in the United States. Among all patients receiving dialytic therapy for their end-stage renal disease (ESRD) in the United States, less than 20% receive some type of PD. The percentage of patients receiving PD between the years 1986 and 1995 has remained relatively unchanged [1, 2]. The explanation for PD's failure to increase in importance appears related to its inability to retain patients [1–5]. The incidence of newly trained PD patients remains high (approximately 20% of all new dialysis patients) [1, 2], and the transplantation and mortality rates of PD patients are generally similar to those of a matched hemodialysis population [1, 2]. Thus, an excessive transfer of continuous ambulatory PD (CAPD) patients to center hemodialysis probably accounts for the stagnant size of the PD population. The reasons for these transfers are not fully characterized, although the following hypotheses have evoked substantial support: frequent peritonitis, recurrent catheter infection, inordinate stress with resulting psychosocial adjustment problems, peritoneal membrane failure, poor patient compliance, patient "burn out," and a belief that present prescription practices favor excess morbidity [2–7].

Although the percentage of ESRD patients receiving PD has not changed significantly over the past five years, the type of PD performed has changed dramatically in the past three years. An increasing percentage of patients now use some form of cycler therapy for PD. The U.S. Renal Data System reports that the percentage of PD patients using cycler therapy has increased from 15% in 1995 to more than 22% in 1996 [2]. This increase in cycler use appears to have coincided with the introduction of several new devices that appear to simplify the PD regimen for cycler patients.

Despite the increase in the popularity of PD cycler therapy, there is a paucity of data regarding cycler adequacy and prescription. The Health Care Financing Administration Peritoneal Dialysis Core Indicators Study (HCFA PD-CIS) is a cross-sectional prevalence survey describing the U.S. PD population and several outcome indicators on an annual basis [8]. Because there are substantial regional variations in the percentage of patients using PD and because both patient characteristics and dialysis methods influence treatment results, this report describes a representative national sample for comparative assessment. An earlier survey (1995 PD-CIS) revealed that anemia treatment practices were relatively uniform across the United States, but detected substantial variability in PD prescription practices and the measurement of PD "adequacy" [9]. This manuscript reviews the data collected for the 1997 survey and investigates the hypothesis that dialysis prescriptions are altered to sustain minimal "adequacy" standards.

METHODS

A stratified random sample of 1375 adult (age 18 years or more) PD patients alive on December 31, 1996 (approximately 5% of the adult PD population stratified by ESRD Network), was identified by the HCFA for inclusion in the 1997 PD-CIS cohort. Analysis was restricted to patients who had not received hemodialysis during the study period but who had been on PD during part or all of the six-month reporting interval.

In July 1997, regional ESRD networks mailed standardized questionnaires to the dialysis providers serving each selected patient. The data abstraction form requested information on patient demographics, primary diagnosis, and laboratory and clinical parameters for each two-month interval during the six-month survey (November through December 1996, January through February 1997, and March through April 1997). Dialysis unit personnel were instructed to obtain the medical charts for each sampled patient and to record all of the treatment modalities used by the patient (CAPD, cycler, or hemodialysis), and for each two-month period the first available entry for serum albumin level (including the laboratory method used to determine these results); hematocrit; systolic and diastolic blood pressure; 24-hour dialysate for volume, urea and creatinine; 24-hour urine for volume, urea and creatinine; calculated weekly Kt/V urea and creatinine clearance [including the method by which volume (V) and body surface area (BSA) were determined]; plasma urea and creatinine; and patient weight and height. Completed forms were returned to their respective ESRD network office for data confirmation and computer entry. These data were then forwarded to the HCFA for aggregation and analysis.

Measures of dialysis adequacy were obtained using both reported values provided by individual dialysis centers and values calculated from raw data. The calculation of weekly Kt/V urea and creatinine clearances was performed by standard methods using data from 24-hour dialysate and urine collections. Creatinine values were not corrected for potential interference by glucose, and no attempt was made to determine the timing of the serum samples used for adequacy measures. For Kt/V urea, residual renal function was calculated using urine urea clearance only. For creatinine clearance, residual renal function was calculated to be the average of the urine urea and creatinine clearances. The volume was determined by the method of Watson [10], and the body surface area was calculated using the formula by duBois and duBois [11].

Data analyses were performed using Epi Info version 6.04 [12] and SPSS for Windows version 6.1 [13]. Analytic methods included the calculation of descriptive parameters, including percentiles for distributions in which the mean and median values differed. Comparative testing used the two-tailed Student's *t*-test assuming equal variances and chi-square analyses. A two-tailed P value of less than 0.05 was considered significant. Logistic regression analyses were conducted to determine significant predictors for calculated weekly Kt/V urea and creatinine clearance below those recommended by the National Kidney Foundation Dialysis Outcome Quality Initiatives (NKF-DOQI) guidelines [14]. These DOQI guidelines include a weekly Kt/V urea of at least 2.1 and a creatinine clearance of at least 63 liter/week/1.73 m^2 for CCPD patients and a weekly Kt/V urea of at least 2.2 and a creatinine clearance of at least 66 liter/week/1.73 m^2 for nocturnal intermittent peritoneal dialysis (NIPD) patients. A backward stepwise regression procedure was employed to obtain the final model. Only predictors with a P value of less than 0.05 were retained in the final model.

RESULTS

Response rate

The response rate for the 1997 PD survey was 89%. Of the 1219 patients for whom data were received, 521 (43%) received cycler PD for all or part of the six-month period of observation. The demographic characteristics of the cycler versus the CAPD cohort are depicted in Table 1; there were no significant demographic differences between CAPD and cycler patients.

Measurement of dialysis adequacy

Peritoneal dialysis adequacy was assessed by two different methods. First, the survey obtained raw data that allowed for the calculation of weekly Kt/V urea and creatinine clearances. Second, the survey asked for the weekly Kt/V urea and creatinine clearance values calculated by either the dialysis center or the center's clinical laboratory. For the cycler cohort, a weekly Kt/V urea was calculated from raw data in 69% of patients, for

Table 1. Characteristics of adult (≥18 years) peritoneal patients in the ESRD Core Indicators Study, 1997

	CAPD	Cycler patients
Total [*N (%)*]	757 (100)	521 (100)
Gender [*N (%)*]		
Males	378 (50)	279 (54)
Females	379 (50)	242 (46)
Race [*N (%)*]		
African American	201 (27)	116 (22)
Caucasian	477 (63)	357 (69)
Other/unknown	79 (10)	48 (9)
Age group *years* [*N (%)*]		
18–44	192 (25)	140 (27)
45–64	362 (48)	228 (44)
65+	203 (27)	153 (29)
Primary diagnosis [*N (%)*]		
Diabetes mellitus	260 (34)	179 (34)
Hypertension	166 (22)	114 (22)
Glomerulonephritis	142 (19)	89 (17)
Other/unknown	189 (25)	139 (27)
BSA *mean* ± SD, m^2	1.85 ± 0.25	1.84 ± 0.25
Median	1.85	1.80
Duration of dialysis		
Mean ± SD, *years*	2.76 ± 3.4	2.52 ± 3.1
Median, *years*	1.70	1.50

P value <0.01 for comparison between CAPD and cycler patients

weekly creatinine clearance in 68% of patients, and for both Kt/V urea and creatinine clearance in 64% of patients. Reported values were available for approximately one third of patients who did not have a calculated adequacy value. In total, using either calculated or reported values, adequacy values were available during the six-month period of observation for 76% of patients for weekly Kt/V urea, 74% for creatinine clearance, and 72% for both adequacy values.

Dialysis adequacy values

The mean calculated weekly Kt/V urea and creatinine clearances in the cycler cohort were 2.24 ± 0.56 and 67.45 ± 24.4 liter/1.73 m^2, respectively, and the median values were 2.20 and 62.25, respectively. Histograms depicting the distribution of these values are shown in Figures 1 and 2. Twenty-two percent of the entire cohort were unable to meet NKF-DOQI guidelines, as they did not have at least one adequacy measure during the six-month period of observation. Only 36% of all patients surveyed met NKF-DOQI guidelines for weekly Kt/V urea. Thirty-three percent met guidelines for weekly creatinine clearance, and 24% met guidelines for both Kt/V urea and creatinine clearance. Therefore, a significant proportion of cycler patients were receiving inadequate dialysis as defined by NKF-DOQI guidelines. If only the approximately three quarters of patients with at least one adequacy measure were analyzed, then 48% of cycler patients met guidelines for Kt/V urea; 44% met guidelines for creatinine clearance, and 32% met guidelines for both Kt/V urea and creatinine clearance. Figures 3 and 4 demonstrate the relationship between adequacy of dialysis and both duration of dialysis (a surrogate for residual renal function) and body size. Note that for weekly Kt/V urea adequacy measures declined as either duration of dialysis or BSA increased. A similar but less consistent pattern was seen regarding weekly creatinine clearances.

Table 2 depicts the risk factors associated with an increased likelihood of receiving inadequate dialysis according to DOQI guidelines. For Kt/V urea, males and patients in the 25^{th} to highest BSA quartile were at increased risk of receiving inadequate dialysis in comparison to females and patients in the lowest BSA quartile. By logistic regression analysis, among patient characteristics examined (Table 3), only duration of dialysis greater than two years, being in the 25^{th} to 50^{th} BSA quartile or highest quartile of BSA and male gender were significant predictors for having calculated weekly Kt/V urea values below that recommended by DOQI guidelines. For weekly creatinine clearance, females and patients on dialysis for more than one year were at increased risk of receiving inadequate dialysis in comparison to males and patients on dialysis for less than one year. By logistic regression analysis, being on dialysis for more than two years, being in the 25^{th} to 50^{th} BSA quartile or highest quartile of BSA and female gender remained as significant predictors for having weekly calculated creatinine clearance values below that recommended by DOQI guidelines.

Dialysis adequacy in cycler patients can be improved by increasing the nighttime dwell volume, optimizing the number and/or length of nighttime exchanges, or by increasing the number of daytime exchanges. The mean prescribed 24-hour volume was 12,040 ± 3255 ml, and the median prescribed volume was 11,783 ml. Figure 5 depicts the relationship between the prescribed daily dialysate volume and both body size and duration of dialysis, the latter a surrogate of residual renal function. Although the average prescribed volume in cycler patients increased from 11,778 ml in patients dialyzed for less than two years to 12,446 ml in patients dialyzed for greater than two years, the calculated weekly Kt/V urea declined from 2.31 ± 0.53 in patients with a duration of dialysis less than one year to 2.15 ± 0.54 in patients with a duration of dialysis greater than two years. The calculated weekly creatinine clearance declined from 75 ± 29 liter/week/1.73 m^2 in patients with a duration of dialysis less than one year to 60 ± 17 liter/week/1.73 m^2 in patients with a duration of dialysis greater than two years. Therefore, although the dialysis prescription is adjusted to account for the decline in residual renal function, the adjustment is still not sufficient to prevent, on average, a decline in the dose of dialysis provided.

One of the most effective methods for increasing dialysis adequacy is to increase dwell volumes. Although the

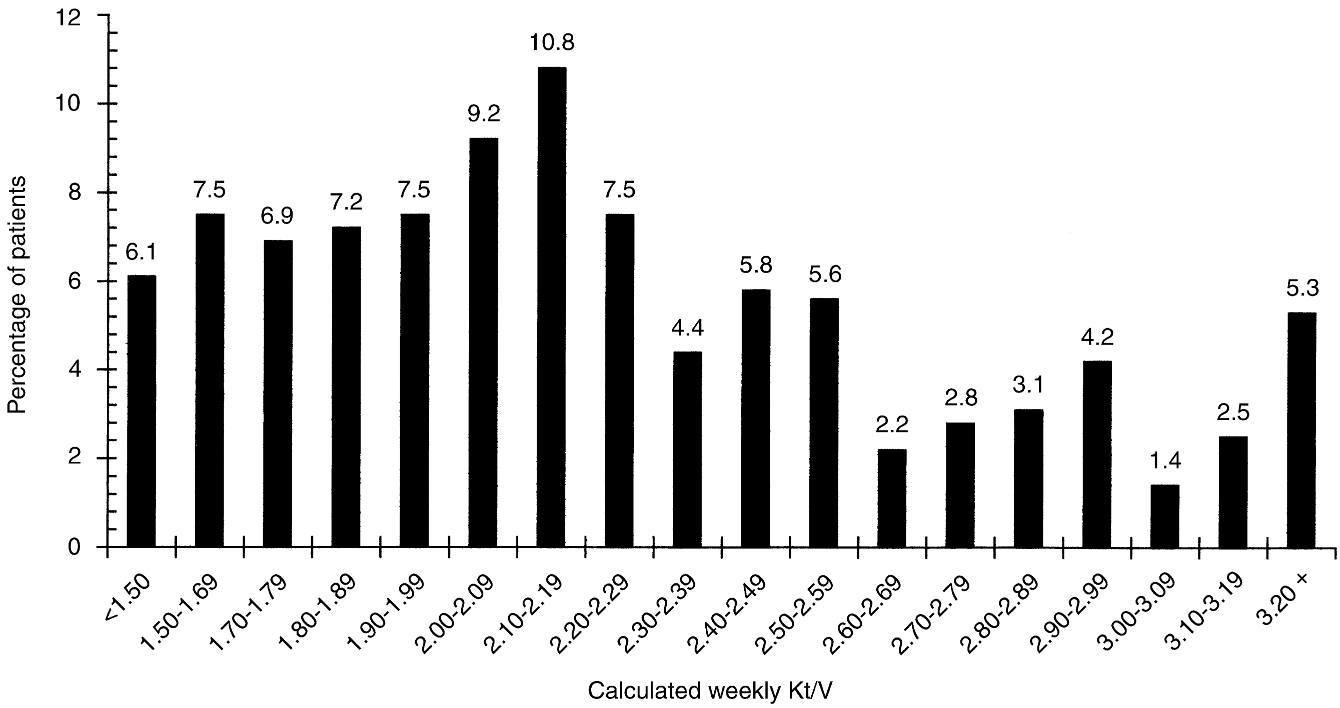

Fig. 1. Distribution of the calculated weekly Kt/V urea values in the 1997 peritoneal dialysis (PD) cycler cohort.

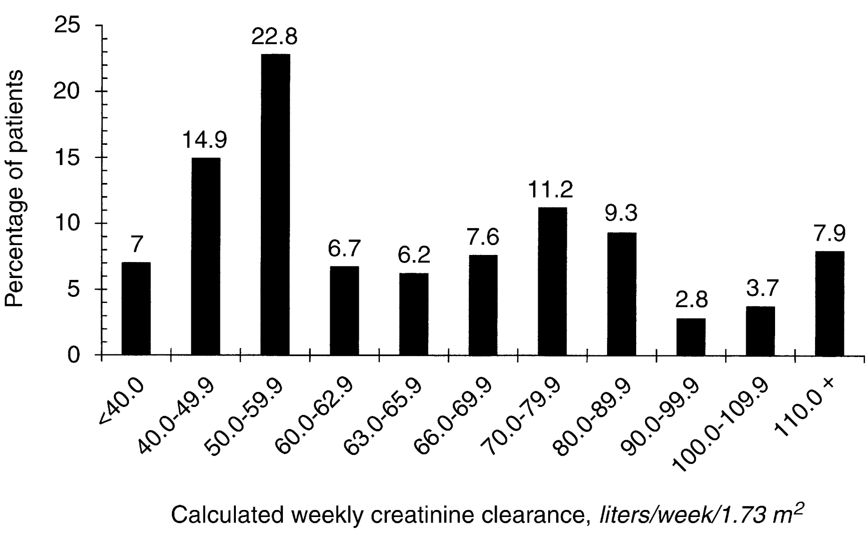

Fig. 2. Distribution of the calculated weekly creatinine clearance values in the 1997 PD cycler cohort.

average PD cycler patient has a BSA of 1.84 ± 0.25 m^2, the median nighttime and daytime dwell volumes were only 2000 ml. The distribution of nighttime and daytime dwell volumes is depicted in Figure 6. For nighttime dwell volumes, 39.8% of patients had 2000 ml dwell volumes; 22.7% had 2500 ml dwell volumes, and 15.7% had dwell volumes between 2000 and 2500 ml. Note that, on average, daytime dwell volumes were lower than nighttime dwell volumes. The distributions of nighttime and daytime dwell volumes by BSA and duration of dialysis are shown in Table 4. For patients on dialysis for greater than two years (presumably with negligible residual renal function), the average dwell volumes were 2219 ± 368 ml at night and 1952 ± 493 ml during the day. An analysis of the appropriateness of nighttime dwell times is more difficult to perform because the optimal dwell time will be dependent on peritoneal transport characteristics. The distribution of nighttime dwell times is shown in Figure 7. Daytime dwell times were uniformly distributed between 240 and 960 minutes. The distribu-

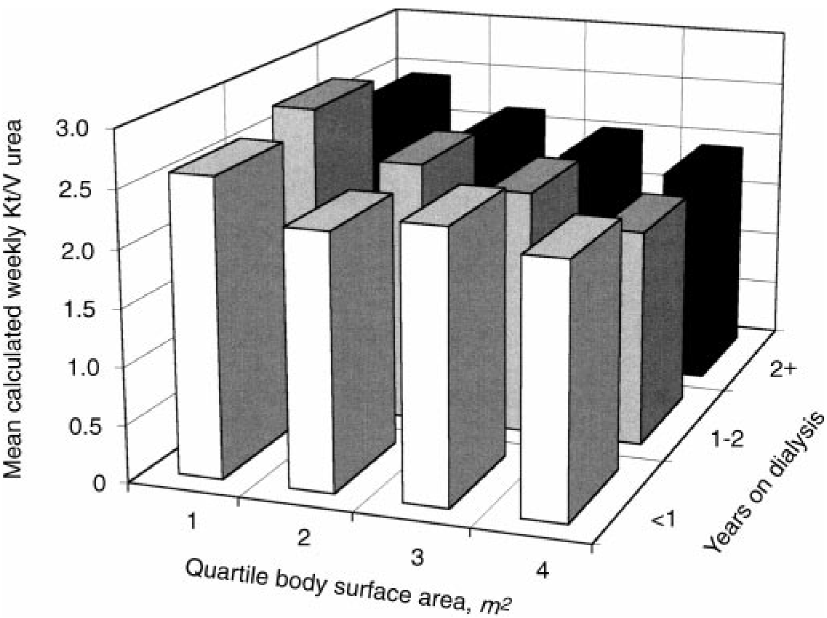

Fig. 3. Relationship between calculated weekly Kt/V urea, body surface area, and duration of dialysis.

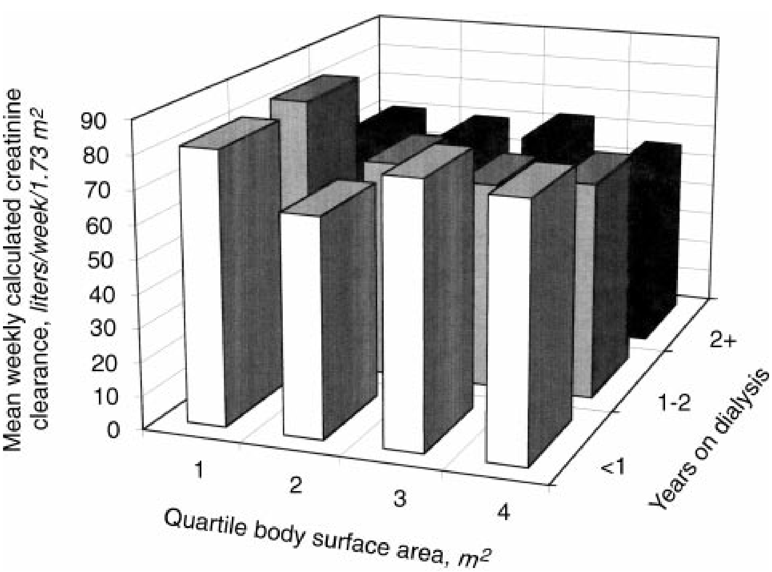

Fig. 4. Relationship between calculated weekly creatinine clearance, body surface area, and duration of dialysis.

tion of the number of daytime and nighttime exchanges is shown in Figure 8. Only 60% of cycler patients were prescribed at least one daytime dwell, and the vast majority of patients received only one daytime dwell. Within each sector of a matrix consisting of duration of dialysis and body size, patients receiving inadequate dialysis were more likely not to have a daytime dwell than patients receiving adequate dialysis.

DISCUSSION

This is the first report of dialysis adequacy in a large, national prevalent sample of PD cycler patients in the United States. Our data demonstrate that a large proportion of cycler patients received less than adequate dialysis in early 1997, prior to the dissemination of the NKF-DOQI guidelines for dialysis adequacy. Only 32% of all patients for whom adequacy measures were available met NKF-DOQI guidelines for both weekly Kt/V urea and creatinine clearance.

Although the adequacy guidelines for cycler therapy are opinion based, theoretical analysis supports the recommendation that cycler adequacy levels should be higher than the evidence-based CAPD adequacy guidelines [15]. We have demonstrated that the risk of inadequate dialysis increases with longer duration of dialysis (a surrogate for loss of residual renal function) and higher body surface area. The observation that males were at increased risk of inadequate dialysis as measured by Kt/V and that females were at increased risk of inadequate

Table 2. Mean calculated weekly Kt/V urea and creatinine clearance values in 1997 PD-CIS cycler patients

	Kt/V urea		Creatinine clearance[a]		Percent meeting DOQI guidelines for both Kt/V and C_{Cr}
	Mean	% meeting DOQI guidelines[b]	Mean	% meeting DOQI guidelines	
Total	2.24 ± 0.56	36	67.45 ± 24.4	33	24
Gender					
Males	2.08 ± 0.50[e]	27[e]	70.52 ± 25.4[d]	38[d]	25
Females	2.42 ± 0.56	47	63.74 ± 22.6	26	24
Race					
African American	2.16 ± 0.58	31	63.96 ± 23.8	27	20
Caucasian	2.25 ± 0.54	38	68.72 ± 24.8	35	25
Other/unknown	2.26 ± 0.63	39	62.88 ± 19.3	26	24
Age group *years*					
18–34	2.27 ± 0.62	36	70.28 ± 26.6	36	27
45–64	2.24 ± 0.58	37	66.36 ± 23.7	33	25
65+	2.20 ± 0.45	37	66.51 ± 23.3	29	22
Primary diagnosis					
Diabetes mellitus	2.30 ± 0.55	38	71.14 ± 27.3	36	26
Hypertension	2.21 ± 0.54	38	65.48 ± 20.0	25	19
Glomerulonephritis	2.25 ± 0.64	32	63.30 ± 22.3	36	27
Other/unknown	2.17 ± 0.51	34	67.50 ± 24.9	32	24
Years on dialysis					
<1	2.31 ± 0.53	41	74.98 ± 29.0[e]	43[e]	32[d]
1–2	2.26 ± 0.63	35	67.92 ± 22.8	33	24
2+	2.15 ± 0.54	32	59.57 ± 16.5	22	17
Quartile BSA (m^2)					
<25th percentile–low	2.53 ± 0.63[e]	55[e]	70.03 ± 25.8	37	34[c]
25th-50th percentile	2.21 ± 0.50	36	63.12 ± 19.4	32	20
50th-75th percentile	2.19 ± 0.45	47	69.60 ± 22.0	47	34
>75th percentile–high	2.03 ± 0.53	29	66.69 ± 28.7	34	24

[a] liter/week/1.73 m^2
[b] DOQI guidelines: For cycler patients with daytime dwell: Kt/V urea ≥2.1, creatinine clearance ≥63 liter/week/1.73 m^2. For cycler patients without a daytime dwell: Kt/V urea ≥2.2, creatinine clearance ≥66 liter/week/1.73 m^2
Statistically significant differences between patient characteristic groups denoted by: [c] $P < 0.05$, [d] $P < 0.01$, [e] $P < 0.001$

Table 3. Predictors of inadequate adequacy measures

Patient characteristic	Odds ratio (95% CI)	*P* value
For weekly Kt/V urea		
Male gender	2.5 (1.5, 4.0)	<0.001
Duration of dialysis *years* (referent = <1)		
1–2 years	1.5 (0.82, 2.7)	0.1949
2+ years	2.1 (1.2, 3.5)	<0.01
BSA quartile (referent = lowest quartile)		
<25th–50th percentile	2.6 (1.3, 5.1)	<0.01
50th–75th percentile	1.6 (0.80, 3.2)	0.1891
>75th percentile	3.4 (1.7, 6.9)	<0.001
For weekly creatinine clearance		
Female gender	2.8 (1.6, 4.6)	<0.001
Duration of dialysis *years* (referent = <1)		
1–2 years	1.7 (0.95, 3.1)	0.0740
2+ years	4.2 (2.5, 7.1)	<0.001
BSA quartile (referent = lowest quartile)		
<25th–50th percentile	2.6 (1.3, 5.1)	<0.01
50th–75th percentile	1.8 (0.90, 3.6)	0.0974
>75th percentile	3.3 (1.6, 6.9)	<0.01

dialysis as measured by creatinine clearance is probably a result of mathematical artifact. For a given BSA, men have a higher volume than women; conversely, for a given volume, women have a higher BSA than men [16, 17].

We were unable to assess the adequacy of dialysis in this six-month period in approximately one quarter of the PD cycler cohort, and it is possible that these patients were at higher risk of receiving inadequate dialysis, as there were no adequacy data available to adjust these patients' prescriptions. Our data are not directly compa-

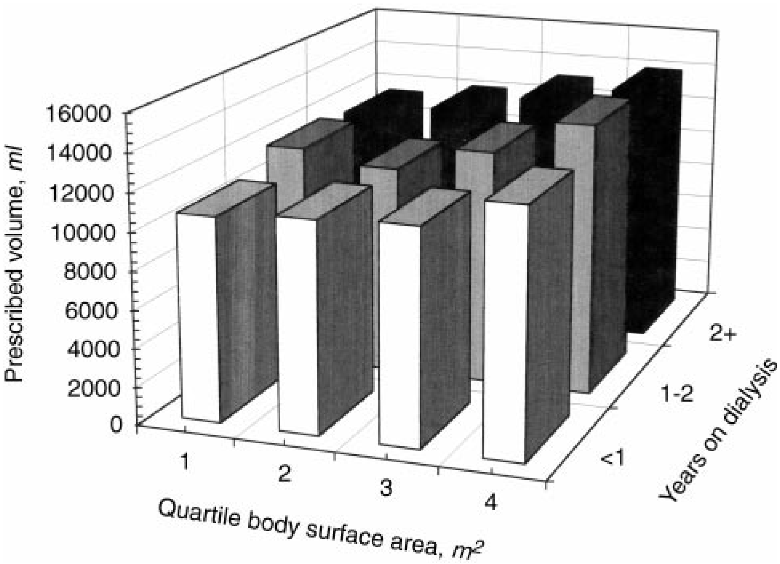

Fig. 5. Relationship between prescribed daily dialysate volume, body surface area, and duration of dialysis.

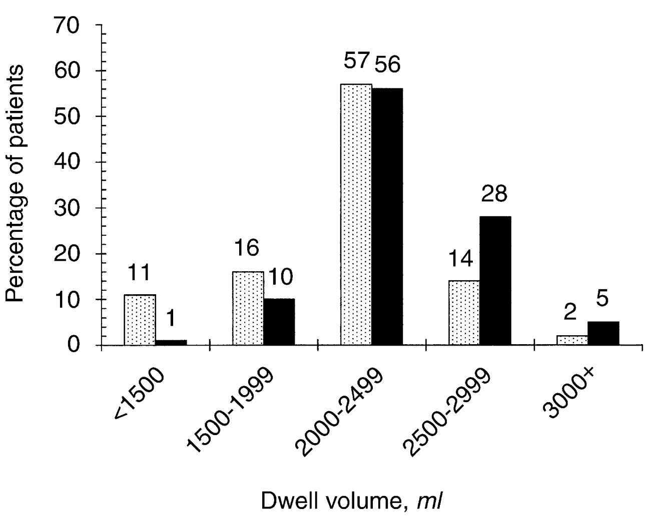

Fig. 6. Distribution of nighttime (■) and daytime (▒) dwell volumes in the 1997 PD cycler cohort.

rable to the USRDS Dialysis Morbidity and Mortality Wave 2 data, as the U.S. Renal Data System study recorded PD prescriptions in only incident patients at approximately day 60 of chronic dialysis therapy [2].

Because PD cycler therapy is more costly, requires a mechanical device in the home, and uses more dialysate than CAPD [18, 19], it had traditionally been reserved for the management of dependent patients who require dialysis assistance, "high transport" patients, and children [18, 20]. More recent reports have indicated that cycler therapy, compared with CAPD therapy, results in reduced peritonitis risk [18, 19, 21–23], better compliance with the PD prescription [24], and higher patient preference [25]. The use of cycler therapy has taken on increasing importance in the last three years, coincident with the development of new, compact cycler machines by several different dialysis equipment manufacturers. Both the U.S. Renal Data System and our PD-CIS surveys have documented a significant increase in the percentage of patients who use the cycler modality of PD, with a corresponding decline in the percentage of patients using CAPD [2]. There are also significant regional variations in the use of PD cycler therapy among the 18 ESRD networks (data not shown), and the rationale for these national and regional differences is not well understood. With the exception of a slightly lower African American enrollment into cycler therapy, this survey did not identify a major difference in reported patient characteristics to explain assignment to CAPD or cycler therapy. Clearly, neither age, gender, weight, primary diagnosis, nor peritoneal equilibrium test (PET) membrane characteristics are the primary determinants of modality selection among adult PD patients. A physiologic rationale for the choice of a specific PD modality is based on the analysis of peritoneal membrane transport characteristics. Patients defined as "high or rapid transporters" are presumably candidates for cycler therapy because they can achieve high clearances with short dwell times of less than three hours, whereas those with "slow or low permeability" membranes should use CAPD [26–29] because they more readily achieve higher clearances with dwell times of five to eight hours. In our PD-CIS survey, however, the average dialysate to plasma ratio for creatinine from the PET was 0.68 in both CAPD and cycler patients. Finally, social factors may be the major determinant in choosing cycler therapy [25, 28], and ultimately, both cost and reimbursement impact this choice [19, 28].

The patient subgroup at the highest risk for less than

Table 4. Mean dwell volumes by BSA and duration of dialysis

	Mean nighttime dwell volume (ml ± SD) Duration of dialysis			Mean daytime dwell volume (ml ± SD) Duration of dialysis		
BSA quartile	<1 year[b]	1–2 years[b]	>2 years[b]	<1 year[b]	1–2 years[a]	>2 years[b]
<25th	1987 (±306)	2092 (±262)	1964 (±327)	1736 (±520)	1612 (±591)	1720 (±457)
25th–50th	2186 (±439)	2049 (±298)	2234 (±359)	1822 (±454)	1788 (±415)	1872 (±481)
50th–75th	2173 (±282)[c]	2259 (±353)	2346 (±300)	1796 (±472)[d]	1938 (±336)	2171 (±330)
>75th	2322 (±317)	2509 (±469)	2383 (±357)	2171 (±409)	2156 (±434)	2177 (±553)

By duration of dialysis, statistically significant differences among quartiles of BSA: [a] $P < 0.05$, [b] $P < 0.001$
By quartile at BSA, statistically significant differences among duration of dialysis categories: [c] $P < 0.05$ for nighttime; [d] $P < 0.01$ for daytime

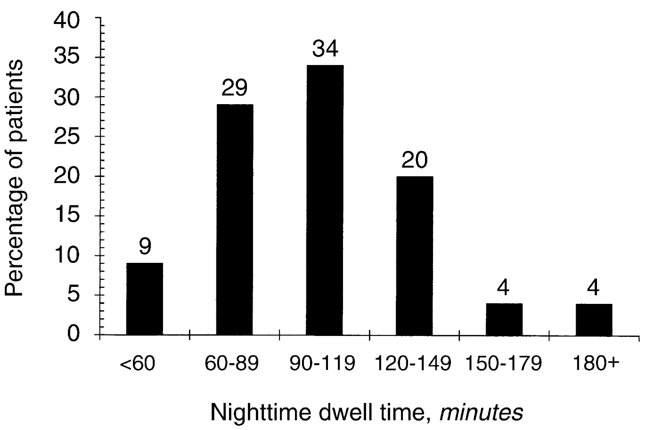

Fig. 7. Distribution of nighttime dwell times in the 1997 PD cycler cohort.

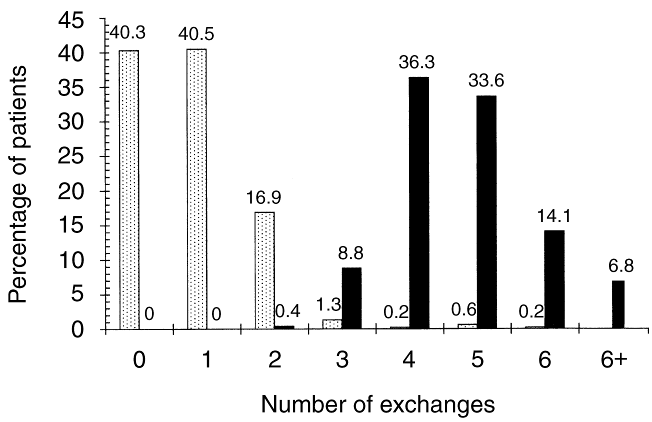

Fig. 8. Distribution of the number of nighttime (■) and daytime (▒) exchanges in the 1997 PD cycler cohort.

adequate PD was the group that had received PD for more than two years. This increased risk of inadequate dialysis occurred despite the observation that patients with a duration of dialysis greater than two years had a higher prescribed 24-hour dialysate volume than patients with a shorter duration of dialysis. In cycler patients, dialysis dose can be increased by several methods, including an increase in the dwell volume, the addition of one or more daytime dwells, and the adjustment of the nighttime dwell number and dwell time. An increase in the dwell volume per exchange is a very effective method for improving dialysis adequacy. A 500 ml increase in the dwell volume per exchange may improve dialysis adequacy by up to 25% [30]. Although it appears that many dialysis health care providers are reluctant to increase dwell volume because of concerns regarding patient discomfort, Piraino et al have demonstrated that blinded patients could not reliably differentiate between 2.0, 2.5, and 3.0 liter dwells [abstract; Piraino et al, *Perit Dial Int* 18(Suppl 1):S22, 1998]. In many cycler patients, the use of one or more daytime dwells will significantly increase the dose of dialysis provided. For anephric patients who are not high transporters, virtually all but the smallest sized patients will require at least one daytime dwell in order to achieve an adequate dose of dialysis. The duration of the daytime dwell should also be adjusted based on the patient's transport characteristics in order to maximize the clearance provided with this exchange(s). Patients who weigh more than 100 kg will almost always require both nighttime cycler exchanges as well as two or more daytime exchanges in order to achieve an adequate dose of dialysis [31]. It is not known, however, if an intensive dialysis schedule increases the risk of noncompliance with the PD prescription and subsequent patient burnout and transfer to hemodialysis [24].

The adjustment of the PD cycler prescription is more complex than for the CAPD prescription because the optimal time for the duration of a single cycler exchange is critically dependent on the patient's transport characteristics. In general, the higher the D/P creatinine ratio from the PET, the shorter the optimal dwell time. In addition, the use of more dialysate volume does not always lead to an increase in the dose of dialysis [30]. Several computer software programs developed by both dialysis equipment manufacturers and by independent companies, as well as nomograms [32, 33], are available and can assist with choosing an initial cycler prescription and providing an estimate of the expected dose of dialysis. The use of either the software programs or nomograms requires information not only about patient size and residual renal function, but also about the patient's transport characteristics from the PET. These transport characteristics, however, were determined in only a minority of patients in the PD-CIS cycler cohort. Unlike CAPD, in which transport characteristics can be estimated from the 24-hour dialysate collection [34], in cycler patients, there is no reliable substitute for the PET for the determination of transport characteristics. Because of initial changes in transport characteristics that occur during the first several weeks of PD therapy [35], the most opportune time to perform the initial PET test is at the conclusion of the PD training period, after at least two weeks of PD have elapsed.

In conclusion, this survey documents that kinetic prescriptions are not often targeted to achieve a level of adequacy of dialysis as recommended by the NKF-DOQI guidelines. Patients at increased risk for inadequate dialysis include those patients with a higher BSA and those with a longer duration of dialysis. Substantial opportunities exist for improvement in dialysis adequacy in PD cycler patients. The first steps needed to provide adequate dialysis are to obtain baseline data on the patient's transport characteristics using the PET and to obtain 24-hour dialysate and urine collections, according to NKF-DOQI guidelines [14], for the determination of adequacy of dialysis. Once this information is available, then a more informed decision can be made regarding the development of an initial cycler prescription that will minimize the risk of receiving inadequate dialysis. The key to the maintenance of adequate dialysis over time is through the routine measurement of dialysis adequacy and the appropriate adjustment of the dialysis prescription as residual renal function declines.

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REFERENCES

1. United States Renal Data System: *USRDS 1996 Annual Data Report.* National Institutes of Health, National Institutes of Diabetes and Digestive and Kidney Diseases, Bethesda, April, 1996
2. United States Renal Data System: *USRDS 1997 Annual Data Report.* National Institutes of Health, National Institutes of Diabetes and Digestive and Kidney Diseases, Bethesda, April, 1997
3. Viglino G, Cancarini G, Catizone L, Cocchi R, De Vecchi A, Lupo A, Salomone M, Segoloni GP, Giangrande A: Ten years of continuous ambulatory peritoneal dialysis: Analysis of patient and technique survival. *Perit Dial Int* 13(Suppl 2):S175–S179, 1993
4. Nolph KD: Technique survival in continuous ambulatory peritoneal dialysis. *Perit Dial Int* 14:222–223, 1994
5. Maiorca R, Cancarini GC, Zubani R, Camerini C, Manili L, Brunori G, Movilli E: CAPD viability: Long-term comparison with hemodialysis. *Perit Dial Int* 16:276–287, 1996
6. Churchill DN, Taylor DW, Keshaviah PR: Adequacy of dialysis and nutrition in continuous peritoneal dialysis: Association with clinical outcomes. Canada-USA (CANUSA) Peritoneal Dialysis Study Group. *J Am Soc Nephrol* 7:198–207, 1996
7. Hays RD, Kallich JD, Mapes DL, Coons SJ, Carter WB: Development of the kidney disease quality of life (KDQOL™) instrument. *Qual Life Res* 3:329–338, 1994
8. HCFA: *1995 Annual Report. ESRD, Core Indicators Project: Opportunities to Improve Care for Adult In-Center Hemodialysis Patients.* Baltimore, Health Care Financing Administration, DHHS, January, 1996
9. Rocco M, Flanigan M, Beaver S, Frederick P, Gentile D, McClellan W, Polder J, Prowant B, Taylor L, Helgerson S: Report from the 1995 core indicators for peritoneal dialysis study group. *Am J Kidney Dis* 30:165–173, 1995
10. Watson PE, Watson ID, Batt RD: Total body water volumes for adult males and females estimated from simple anthropometric measurements. *Am J Clin Nutr* 33:27–39, 1980
11. duBois D, duBois EF: A formula to estimate the approximate surface area if height and weight be known. *Arch Intern Med* 17:863–871, 1916
12. Dean JA, Burton AH, Coulombier D, Brendel KA, Smith DC, Burton AH, Dicker RC, Sullivan K, Fagan RF, Arner TG: *Epi Info Version 6.04a: A word processing database and statistics program for epidemiology on microcomputers.* Atlanta, Atlanta Centers for Disease Control and Prevention, 1996
13. Norusis MJ: *SPSS for Windows Advanced Statistics, Release 6.1.* Chicago, SPSS, Inc., 1993
14. National Kidney Foundation Dialysis Outcomes Quality Initiatives Workgroup: NKF-DOQI clinical practice guidelines for peritoneal dialysis adequacy. *Am J Kidney Dis* 30(Suppl 2):S67–S136, 1997
15. Gotch FA: Kinetic modeling in peritoneal dialysis, in *Clinical Dialysis*, edited by Nissenson AR, Fine RN, Gentile DE, Boston, Appleton and Lange, 1995, pp 343–375
16. Tzamaloukas AH, Malhotra D, Murata GH: Gender, degree of obesity and discrepancy between urea and creatinine clearance in peritoneal dialysis. *J Am Soc Nephrol* 9:497–499, 1998
17. Vonesh EF, Moran J: Discrepancy between urea Kt/V versus normalized creatinine clearance. *Perit Dial Int* 17:13–16, 1997
18. Woodrow G, Turney JH, Cook JA, Gibson J, Fletcher S, Stewart AJ, Brownjohn AM: Nocturnal intermittent peritoneal dialysis. *Nephrol Dial Transplant* 9:399–403, 1994
19. Blake PG, Floyd J, Spanner E, Peters K: How much extra does "adequate" peritoneal dialysis cost? *Perit Dial Int* 16(Suppl 1):S171–S175, 1996
20. Schaefer F, Wolf S, Klaus G, Langenbeck D, Mehls O: Higher KT/V urea associated with greater protein catabolic rate and dietary protein intake in children treated with CCPD compared to CAPD: Mid-European Pediatric CPD Study Group (MPCS). *Adv Perit Dial* 10:310–314, 1994
21. Holley JL, Bernardini J, Piriano B: Continuous cycling peritoneal dialysis is associated with lower rates of catheter infections than continuous ambulatory peritoneal dialysis. *Am J Kidney Dis* 16:133–136, 1990
22. Brunkhorst R, Wrenger E, Krautzig S, Ehlerding G, Mahiout A, Koch KM: Clinical experience with home automated peritoneal dialysis. *Kidney Int* 46(Suppl 48):S25–S30, 1994
23. De Fijter CW, Oe LP, Nauta JJ, van der Meulen J, Verbrugh HA, Verhoef J, Donker AJ: Clinical efficacy and morbidity associated with continuous cyclic compared to continuous ambulatory peritoneal dialysis. *Ann Intern Med* 120:264–271, 1994
24. Bernardini J, Piraino B: Compliance in CAPD and CCPD pa-

tients as measured by supply inventories during home visits. *Am J Kidney Dis* 31:101–107, 1998
25. Wrenger E, Krautzig S, Brunkhorst R: Adequacy and quality of life with automated peritoneal dialysis. *Perit Dial Int* 16(Suppl 1):S153–S157, 1996
26. Keshaviah P: The solute removal index: A unified basis for comparing disparate therapies. *Perit Dial Int* 15:101–104, 1995
27. Rippe B, Krediet RT: Peritoneal physiology-transport of solutes, in *The Textbook of Peritoneal Dialysis*, edited by Gokal R, Nolph K, Norwell, Basel, Kluwer Academic, 1994, pp 69–113
28. Diaz-Buxo JA, Suki WN: Automated peritoneal dialysis, in *The Textbook of Peritoneal Dialysis*, edited by Gokal R, Nolph K, Norwell, Basel, Kluwer Academic, 1994, pp 399–418
29. Strauss FG, Holmes DL, Dennis RL: Dialysis adequacy indices in high membrane transporters treated with short-dwell peritoneal dialysis. *Adv Perit Dial* 11:110–113, 1995
30. Burkart JM, Nolph KD: Peritoneal dialysis, in *The Kidney* (5th ed), edited by Brenner BM, Philadelphia, W.B. Saunders, 1996, pp 2507–2575
31. Tzamaloukas AH, Dimitriadis A, Murata GH, Nicolopoulou N, Malhotra D, Balaskas EV, Kakavas J, Antoniou S, Dombros NV, Batzili E, Voudiklari S: Continuous peritoneal dialysis in heavy-weight individuals: Urea and creatinine clearances. *Perit Dial Int* 16:302–306, 1996
32. Nolph KD, Jensen R, Khanna R, Twardowski ZJ: Weight limitations for adequate therapy using various volumes in CAPD. *Perit Dial Int* 14:261–264, 1994
33. Rocco MV: Body surface area limitations in achieving adequate therapy in peritoneal dialysis patients. *Perit Dial Int* 16:617–622, 1996
34. Rocco MV, Jordan JR, Burkart JM: Determination of peritoneal transport characteristics with 24-hour dialysate collections: Dialysis adequacy and transport test. *J Am Soc Nephrol* 5:1333–1338, 1994
35. Rocco MV, Jordan JR, Burkart JM: Changes in peritoneal transport during the first month of peritoneal dialysis. *Perit Dial Int* 15:12–17, 1995