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Independent Effects of Residual Renal Function and Dialysis Adequacy on Actual Dietary Protein, Calorie, and Other Nutrient Intake in Patients on Continuous Ambulatory Peritoneal Dialysis

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Abstract. Previous studies have suggested that the cross-sectional relationship observed between total solute clearance (Kt/V) and dietary protein intake (DPI) in patients undergoing dialysis is possibly mathematical in origin. A cross-sectional study on 242 patients undergoing continuous ambulatory peritoneal dialysis (CAPD) was performed to determine the differential effects of dialysis adequacy and residual renal function (RRF) on actual dietary intake. All patients underwent a 7-d food frequency questionnaire to quantify daily dietary protein, calorie (DCI), and other nutrient intake, subjective global assessment (SGA), and collection of 24-h dialysate and urine for total (PD and renal) Kt/V and RRF. Patients were categorized into three groups: I ($n = 94$), total Kt/V $\geq$1.7 and GFR $>$0.5 ml/min per 1.73 m^2; II ($n = 58$), total Kt/V $\geq$1.7 but GFR $<$0.5 ml/min per 1.73 m^2; and III ($n = 90$), total Kt/V $<$1.7. Sixty-nine percent *versus* 62% *versus* 42% of group I *versus* II *versus* III patients were well nourished according to SGA ($P = 0.004$). DPI (1.23 [0.47] *versus* 1.12 [0.49] *versus* 0.99 [0.40] g/kg per d; $P = 0.002$) and DCI (27.3 [8.9] *versus* 23.8 [8.6] *versus* 23.0 [8.2] kcal/kg per d; $P = 0.002$) showed significant decline across the three groups. Intake of other nutrients, including carbohydrate, fat, fatty acids, and cholesterol was higher for group I compared with groups II and III. Adjusting for age, gender, weight, and diabetes, every 1 ml/min per 1.73 m^2 increase in GFR was associated with a 0.838-fold increase in DCI (95% confidence interval to interval, 0.279 to 1.397; $P = 0.003$) and a 0.041-fold increase in DPI (95% confidence interval, 0.009 to 0.072; $P = 0.012$), whereas every 0.25-unit increase in total (PD and renal) Kt/V was associated with a 0.570-fold increase in DCI (95% confidence interval, 0.049 to 1.092; $P = 0.032$) and a 0.052-fold increase in DPI (95% confidence interval, 0.023 to 0.081; $P = 0.001$). Greater small-solute clearances are associated with better dietary intake and better nutrition. The study confirmed significant and independent effect of RRF, but not PD solute clearance, on actual DPI, DCI, and other nutrient intake in patients on CAPD.

Continuous ambulatory peritoneal dialysis (CAPD) accounts for 14% of the dialysis modality worldwide (1). Previous studies have indicated that the dialysis dose is one of the major determinants of morbidity and mortality in patients undergoing peritoneal dialysis (PD) (2–3). The CANUSA study indeed confirmed better patient survival, with higher weekly fractional urea clearance (Kt/V) and better nutrition status (4). Providing greater small-solute clearance by dialysis is thought to improve dietary protein intake. This effect of small-solute clearance on dietary protein intake (DPI) was derived from the strong correlation noted between Kt/V and the normalized protein catabolic rate (nPCR) where protein catabolic rate was used as an estimate of DPI (5).

Some investigators observed that PCR determination might not provide a reliable index of actual dietary protein intake in many patients undergoing dialysis (6). Concern has also been raised about the strength of the cross-sectional relationship between Kt/V and nPCR being in part related to the phenomena of mathematical coupling (7), given that they share a common numerator—namely, dialysate urea concentration and dialysate volume—as well as a common denominator—namely, the volume of urea distribution. The presence of one or more variables that are common to both Kt/V and nPCR may increase the correlation coefficient, hence obscuring the true relationship between Kt/V and nPCR and casting doubt on whether the association between small-solute clearance, dietary protein intake, and nutrition status is still valid (7).

Previous studies have suggested an independent contribution of residual renal function (RRF) to the overall nutritional status

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in patients undergoing dialysis (8–9). The independent effect of residual renal function on actual dietary protein intake, however, has not been determined. Effects of small-solute clearance as well as residual GFR on actual dietary calorie and other major nutrients intake in patients undergoing CAPD are also not known.

This study therefore aims to determine the effect of dialysis adequacy on actual dietary protein, calorie, and other nutrient intake as well as nutrition status in patients undergoing CAPD and also to differentiate the effects of dialysis adequacy and RRF on actual dietary protein, calorie, and other nutrient intake.

Materials and Methods

We performed a single-center cross-sectional study on 242 patients undergoing CAPD who have been maintained stably on dialysis for at least 3 mo. The study protocol was approved by the Human Research Ethics Committee of the Chinese University of Hong Kong. Informed consent was obtained from all patients to undergo assessment of their average daily dietary intake, nutrition status, and indices of dialysis adequacy described as follows.

Diet Assessment

All patients completed a 7-d food frequency questionnaire that has previously been validated in the Chinese population (10,11) to quantify and average daily dietary calorie, protein, fat, carbohydrate, fatty acid, and cholesterol intake. Briefly, the food frequency questionnaire consisted of 253 food items, categorized into 7 food types. Items chosen were those most frequently consumed, on the basis of previous local surveys, and included some items of the questionnaire used in the Australian Chinese Dietary Survey. During administration of the questionnaire, patients were asked to complete the questionnaire by recording their diet for the week preceding the interview. They were asked to supply the portion size and frequency of consumption per day or week for each food item. Portion size was explained with a catalogue of pictures of food portions, by using bowls with a volume of 240 ml and plates 17.5 cm in diameter. The amount of cooking oil was estimated according to the method of preparing different foods. Dietary intake of calorie, protein, fat, and carbohydrate were normalized to patients' actual dry body weight (BW), as determined by dual energy x-ray absorptiometry, with the abdomen drained dry of peritoneal fluid.

Nutrition Assessment

Nutrition status was assessed with a subjective global assessment. This has been shown to be a clinically adequate method in assessing nutrition status of patients undergoing dialysis (12). It was performed by experienced research staff, blinded to all clinical and biochemical parameters of patients. Patients were graded to have normal, mild, moderate, or severe malnutrition status accordingly. Dry weight was measured with the abdomen drained dry of peritoneal fluid, without shoes, and in light clothing to the nearest 0.1 kg by use of dual energy x-ray absorptiometry and height to the nearest 0.5 cm. Body mass index was calculated as weight in kilograms divided by height in meters squared. Frame size was calculated as the ratio of height to wrist circumference (13).

Indices of Dialysis Adequacy

Adequacy of dialysis was determined by measurement of total (PD and renal) weekly urea Kt/V and creatinine clearance by use of standard methods (14). The contributions of Kt/V by PD (PDKt/V) and residual renal function (renal Kt/V) were estimated separately. Total weekly Kt/V was calculated as the sum of PDKt/V and renal Kt/V. Residual GFR was calculated as an average of 24-h urine urea and creatinine clearance (15). Creatinine concentration in dialysate was corrected for interference by glucose according to reference formula determined in our laboratory (16). Total body water (V) was derived by use of the Watson formula (17).

Data Collection

Information regarding age, gender, underlying cause of renal failure, and starting date of dialysis was obtained from case records. Duration of dialysis was calculated as the interval between the starting date of dialysis and the date of assessment and was expressed in months.

Patients were divided into three groups according to their total (PD and renal) weekly Kt/V and GFR: group I (n = 94), Kt/V $\geq$1.7 and GFR >0.5 ml/min per 1.73 m^2 (well-dialyzed group with RRF); group II (n = 58), Kt/V $\geq$1.7 but GFR <0.5 ml/min per 1.73 m^2 (dialysis-dependent group with negligible RRF); and group III (n = 90), Kt/V <1.7 (inadequately dialyzed group).

Statistical Analyses

Categorical data were expressed as n (%). Continuous data were expressed as mean (SD) or median (interquartile range), depending on the distribution of the data. Categorical data were compared by use of the χ^2 test. Comparison between groups was performed by use of ANOVA for mean (SD) data and the Kruskal-Wallis test for median (interquartile range) data. *Post hoc* analysis was performed by the Bonferroni method. Linear regression analysis was done to determine the independent effects of dialysis adequacy and residual GFR on dietary protein and calorie intake after controlling for demographic and clinical variables including age, gender, body weight, and presence of diabetes. Statistical analyses were performed by SPSS version 10.0 for Windows software (SPSS, Chicago, IL).

Results

Altogether, 242 patients (125 men and 117 women), all of Chinese origin, were recruited for the study. The mean (SD) age of patients was 55 yr (12), and the mean duration of CAPD was 37 (range, 4 to 151) mo. Underlying renal diagnosis was chronic glomerulonephritis in 78 (32%) patients, diabetic nephropathy in 60 (25%) patients, hypertensive nephrosclerosis in 32 (13%) patients, obstructive uropathy in 13 (5%) patients, polycystic kidney disease in 12 (5%) patients, and tubulointerstitial disease in 7 (3%) patients. Underlying renal disease was not known in 40 (17%) patients.

All three groups were of similar age at the time of study. Significant difference in gender distribution was noted among the three groups; group II had the lowest percentage of male patients (41%), whereas group III had a preponderance of men (61%) (P = 0.039). Group I was on CAPD for significantly shorter duration compared with both groups II and III (18 [12 to 27] *versus* 48 [25 to 74] *versus* 35 [17 to 64] mo, respectively; P < 0.001). A significantly greater proportion of group III patients (39%) had underlying diabetes compared with those in groups I and II (30% and 19%, respectively; P = 0.036) (Table 1).

Groups I, II, and III were maintained on an average (SD) of

Table 1. Clinical characteristics of the 242 patients undergoing continuous ambulatory peritoneal dialysis (CAPD), according to their total weekly Kt/V and residual GFR

Parameter	Group I (n = 94) Total Kt/V ≥1.7 and residual GFR >0.5 ml/min per 1.73 m^2	Group II (n = 58) Total Kt/V ≥1.7 but residual GFR <0.5 ml/min per 1.73 m^2	Group III (n = 90) Total Kt/V <1.7	P
Male, n (%)	46 (49)	24 (41)[d]	55 (61)[d,h]	0.05[a]
Mean age (yr)	56 (12)	54 (12)[d]	55 (12)[d,i]	0.694[b]
CAPD (mo)	18 (12, 27)	48 (25, 74)[e]	35 (17, 64)[f,j]	<0.001[c]
n (%) with diabetes	28 (30)	11 (19)[d]	35 (39)[d,i]	0.036[a]
Body wt (kg)	58 (10)	55 (10)[d]	60 (10)[d,k]	0.008[b]
Body height (m)	1.57 (0.07)	1.56 (0.08)[d]	1.60 (0.08)[g,j]	<0.001[b]
Body mass index (kg/m^2)	23 (3)	23 (4)[d]	23 (3)[d,i]	0.54[b]
Frame size	15.8 (1.1)	15.6 (1.2)[d]	16.0 (1.0)[d,l]	0.04[b]

Data compared by use of [a] χ^2 test, [b] one-way ANOVA, or [c] Kruskal-Wallis test.
[d] P = NS, [e] $P < 0.001$, [f] $P = 0.05$, and [g] $P < 0.05$, compared with group I by Bonferroni *post hoc* analysis.
[h] $P < 0.05$, [i] P = NS, [j] $P = 0.0001$, [k] $P < 0.01$, and [l] $P = 0.05$, group II *versus* group III, by Bonferroni *post hoc* test.

6.2 (0.9), 7.1 (1.3), and 6.6 (1.1) L PD exchanges per day, respectively ($P < 0.001$) to achieve mean total Kt/V of 2.19 (0.44) *versus* 1.96 (0.23) *versus* 1.43 (0.20), respectively ($P < 0.001$; Table 2). When total Kt/V was subdivided into the component contributed by PD (PDKt/V) and that by residual GFR, significant difference was noted in both PDKt/V and GFR among the three groups (Table 2).

The significant intergroup difference in total Kt/V may in part be related to significant difference in BW (58 [10] *versus* 55 [10] *versus* 60 [10] kg; $P = 0.008$) and height (1.57 [0.07] *versus* 1.56 [0.08] *versus* 1.60 [0.08] m; $P < 0.001$) for group I *versus* II *versus* III, respectively (Table 1). An increase or decrease in BW will increase or decrease the denominator of Kt/V and result in a smaller or larger Kt/V, respectively. Among the three groups of patients, group II, with a preponderance of women (59%), had the lowest BW and height, whereas group III, with the highest percentage of male patients (61%), had the highest BW and height. Indeed, group II had significantly smaller frame size than group III (15.6 [1.2] *versus* 16.0 [1.0]; $P = 0.05$) (Table 1). The significant difference in BW between groups II and III may also explain why group II managed to achieve a significantly higher total Kt/V than group III by increasing their PDKt/V, despite having lower residual GFR than group III (Table 2).

Nutrition status was significantly different among the three groups ($P = 0.004$; Figure 1). Among well-dialyzed patients with RRF (group I), 69% were well nourished, 22% had mild malnutrition, and 8.5% were moderately malnourished. There was a trend toward worsening nutrition status in patients who had a loss of RRF despite maintaining total Kt/V ≥1.7 (group II), although this was statistically insignificant. Patients who were considered inadequately dialyzed as defined by total Kt/V <1.7 (group III) showed significantly higher incidence of malnutrition than group I ($P = 0.003$). Only 42% of group III were well nourished. Twenty-nine percent of patients had mild malnutrition, 24% were moderately malnourished, and 4% were severely malnourished. A trend toward better nutrition for group II than group III was also noted ($P = 0.18$).

Average daily DPI and dietary calorie intake (DCI) were higher for group I compared with groups II and III, with a

Table 2. Average daily peritoneal dialysis (PD) exchange volume, with average indices of dialysis adequacy and residual GFR among the three groups of patients[a]

Parameter	Group I (n = 94)	Group II (n = 58)	Group III (n = 90)	P
PD exchange (L/d)	6.2 (0.9)	7.1 (1.3)[c]	6.6 (1.1)[dg]	< 0.001
Total (PD and renal) wkly creatine clearance rate (L/wk per 1.73 m^2)	77 (26)	49 (7)[c]	48 (14)[ce]	< 0.001
Total (PD and renal) wkly Kt/V	2.19 (0.44)	1.96 (0.23)[c]	1.43 (0.20)[cf]	< 0.001
Wkly PD Kt/V	1.53 (0.30)	1.94 (0.24)[c]	1.31 (0.25)[cf]	< 0.001
GFR (ml/min per 1.73 m^2)[b]	2.43 (1.48, 3.59)	0 (0, 0.16)[c]	0.17 (0, 1.26)[cg]	< 0.001

[a] Data are expressed as mean (SD) and compared by use of one-way ANOVA unless specified otherwise.
[b] Data are expressed as median (interquartile range) and compared by use of the Kruskal-Wallis test.
[c] $P < 0.001$, [d] $P < 0.05$, compared with group I by use of the Bonferroni *post hoc* test.
[e] P = NS, [f] $P < 0.001$, and [g] $P < 0.05$, group II *versus* group III, by use of Bonferroni *post hoc* analysis.

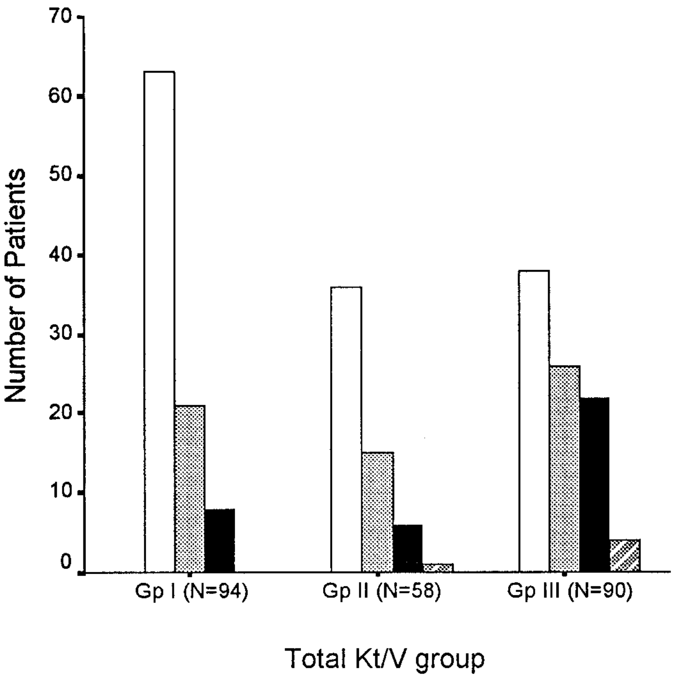

Figure 1. Nutrition status assessed according to subjective global assessment (SGA) in relation to dialysis adequacy and residual renal function in patients undergoing continuous ambulatory peritoneal dialysis (CAPD). ☐;, normal; ▨, mild malnutrition; ■, moderate malnutrition; ▨, severe malnutrition.

tendency toward better DPI and DCI when the total weekly Kt/V was higher (Table 3 and Figure 2). Average daily fat and carbohydrate intake was also higher for group I compared with groups II and III. Among patients with minimal RRF (groups II and III), no significant difference was noted in the dietary protein, fat, carbohydrate, and calorie intake, despite significant difference in PDKt/V (Table 3).

Intake of other nutrients, including saturated fatty acid (13.9 [6.2] *versus* 10.9 [5.6] *versus* 11.9 [5.7] g; $P = 0.006$), monounsaturated fatty acid (19.3 [8.0] *versus* 15.6 [7.5] *versus* 17.1 [8.1] g; $P = 0.015$), polyunsaturated fatty acid (12.1 [6.4] *versus* 9.4 [4.6] *versus* 10.1 [5.1] g; $P = 0.007$), and cholesterol (228 [118] *versus* 179 [81] *versus* 171 [89]; $P < 0.001$), were significantly different among the three groups. Nutrient densities indicated that reduced nutrient intake for groups II and III compared with group I was attributed to an overall reduction in DCI but not any particular dietary intake pattern for groups II and III.

After controlling the effect of age, gender, BW, and diabetes, every 0.25-unit increase in the total weekly Kt/V remained significantly associated with a 0.570-fold increase in DCI ($P = 0.032$) and a 0.052-fold increase in DPI ($P = 0.001$), whereas every 1 ml/min per 1.73 m^2 increase in the GFR was significantly associated with a 0.838-fold increase in DCI ($P = 0.003$) and a 0.041-fold increase in DPI ($P = 0.012$) (Table 4). No association, however, was noted of the PDKt/V with DCI or DPI.

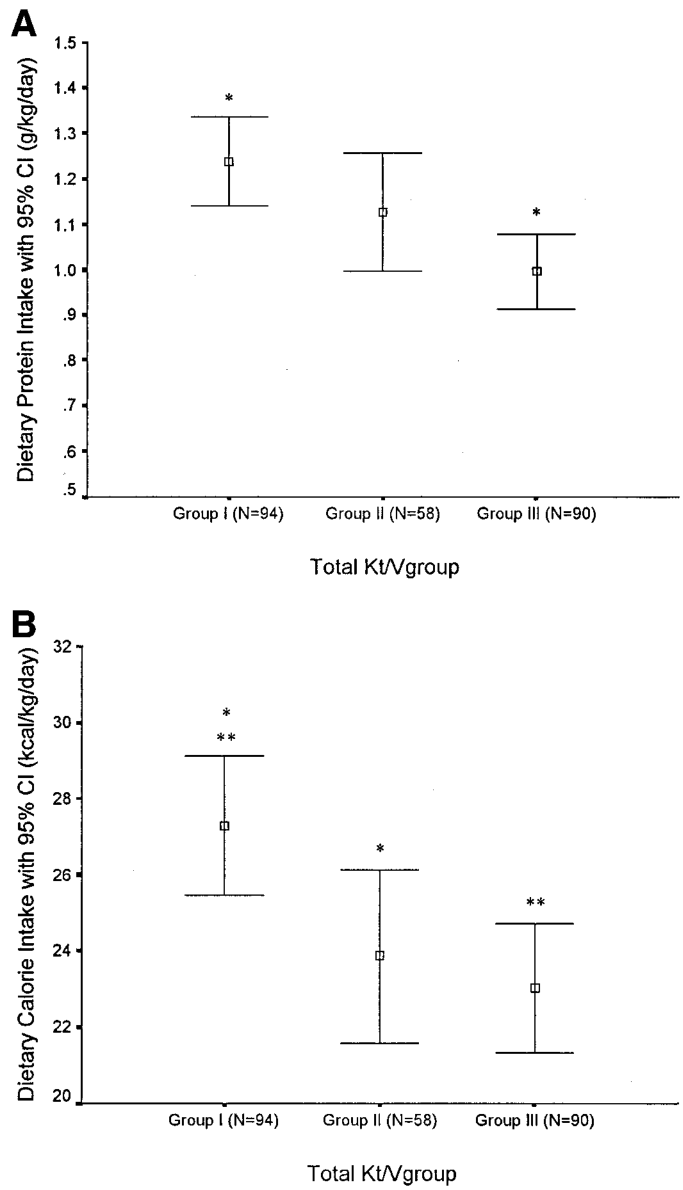

Figure 2. (A) Average daily dietary protein intake and (B) average daily dietary calorie intake among patients undergoing CAPD with different indices of dialysis adequacy and residual renal function. Panel A, overall $P = 0.002$; *, $P = 0.001$, group I vs. group III. Panel B, overall $P = 0.002$; *, $P = 0.05$, group I *versus* group II; **, $P < 0.005$, group I *versus* group III.

Discussion

Protein-energy malnutrition is an important complication in patients undergoing dialysis and is associated with significant morbidity and mortality (2,4,18). Assessment of DPI and DCI therefore becomes crucial in monitoring the nutritional status of these patients. To date, PCR, obtained from urea nitrogen appearance, is used to provide an indirect estimate of the actual DPI (19). However, the application of this method requires the assumption that the patient is metabolically stable. Moreover, direct measurement of habitual dietary intake of patients undergoing CAPD is usually not done. Estimates of intake are based on normalized protein nitrogen appearance. DCI, as well

Table 3. Average daily dietary protein, fat, carbohydrate, and calorie intake of patients undergoing CAPD according to the weekly urea clearance and residual renal function[a]

Parameter	Group I (n = 94)	Group II (n = 58)	Group III (n = 90)	P
Protein (g)	70 (26)	59 (22)[b]	60 (24)[b,h]	0.006
Fat (g)	53 (21)	41 (17)[c]	45 (20)[b,h]	0.001
Carbohydrate (g)	198 (63)	166 (58)[d]	183 (66)[f,h]	0.009
Total calorie (kcal)	1541 (454)	1268 (414)[e]	1367 (468)[b,h]	0.001
Protein (g/kg body wt)	1.23 (0.47)	1.12 (0.49)[f]	0.99 (0.40)[e,h]	0.002
Fat (g/kg body wt)	0.93 (0.38)	0.75 (0.33)[f]	0.80 (0.39)[f,h]	0.010
Carbohydrate (g/kg body wt)	3.47 (1.31)	3.01 (1.20)[b]	3.22 (1.20)[f,h]	0.094
Calorie (kcal/kg body wt)	27.3 (8.9)	23.8 (8.6)[g]	23.0 (8.2)[c,h]	0.002
% daily calorie intake contributed by				
dietary protein	18 (4)	19 (4)[f]	17 (4)[f,h]	0.133
dietary fat	31 (8)	29 (6)[f]	29 (7)[f,h]	0.323
dietary carbohydrate	52 (9)	52 (7)[f]	54 (9)[f,h]	0.414

[a] Data expressed in mean (SD) and compared by use of one-way ANOVA.
[b] $P < 0.05$, [c] $P < 0.005$, [d] $P < 0.01$, [e] $P = 0.001$, [f] P = NS, and [g] $P = 0.05$, compared with group I by use of the Bonferroni *post hoc* test.
[h] P = NS, group II *versus* group III by use of the Bonferroni *post hoc* test.

Table 4. Linear regression analysis showing significant and independent effects of total weekly Kt/V and residual GFR on dietary protein and calorie intake in patients undergoing CAPD after adjustment for age, gender, body weight, and diabetes

Parameter	Estimated Mean	95% Confidence Interval	P
Protein (g/kg per d)[a]	0.052	(0.023–0.081)	0.001
Calorie (kcal/kg per d)[a]	0.570	(0.049–1.092)	0.032
Protein (g/kg per d)[b]	0.041	(0.009–0.072)	0.012
Calorie (kcal/kg per d)[b]	0.838	(0.279–1.397)	0.003

[a] In relation to every 0.25-unit increase in total weekly Kt/V.
[b] In relation to every 1 ml/min per 1.73 m^2 increase in residual GFR.

as intake of other nutrients, is also not assessed. Herein, we examined actual dietary intake of different nutrients in a large cohort of Chinese patients undergoing CAPD by using a 7-d food frequency questionnaire that has been validated in the Chinese population. With substantial differences between the Asian and western diets, quite a number of Chinese food items are not available in the food frequency questionnaire that has been in use for Western populations. Moreover, cooking methods differ greatly between Asian and western populations. It is therefore essential to assess habitual dietary intake on the basis of a questionnaire that has been well validated in the local population.

On the basis of the linear relationship noted between Kt/V and nPCR in patients undergoing both hemodialysis and CAPD, previous studies suggested a link among dialysis therapy, dietary protein intake, and nutrition status (20–22). Some studies, however, pointed out that the cross-sectional correlation between PCR and Kt/V may be mathematical in origin, given that they are both derived from common factors (7,23). The present study is the first to investigate the independent effects of peritoneal small-solute clearance and RRF on actual DPI, DCI, and other nutrient intake and validate the relationship among dialysis dose, RRF, dietary intake, and nutrition status in the clinical setting. Anorexia with reduced dietary protein and energy intake can result from inadequate dialysis and predispose to malnutrition. Improved efficiency of uremic toxin removal may stimulate appetite and hence improve dietary intake. This concept is supported by animal experiments that have demonstrated that intraperitoneal injection of uremic toxins with a molecular weight between 1.0 and 1.5 kD into normal rats suppresses appetite and food intake in a dose-related fashion (24). Reduced appetite and dietary intake in patients with uremia has been partly attributed to altered taste perception and impaired taste sensitivity (25–26). Improvement in taste was noted immediately after dialysis, although not to normal levels (27), which implicates the accumulation of uremic toxins between dialysis as the etiology for impaired taste perception. The CANUSA study indeed confirmed improvement of appetite with initiation of dialysis in patients who had renal failure (18). One study in patients undergoing hemodialysis also demonstrated an increase in DCI after improvement in taste acuity (28). However, the exact toxins responsible for appetite suppression in uremia have yet to be identified.

Previous longitudinal studies that tried to determine the effects of Kt/V on PCR yielded inconclusive results. Although some studies observed improvement in nPCR with increased Kt/V (29), other studies failed to confirm this observation (30,31). This may be related to the relatively small sample size and uncontrolled nature in most of these studies. This study, although cross-sectional in nature, confirms a clear association between dialysis adequacy and DPI rather than simply mathematical coupling. A significant positive correlation was also observed between actual DPI and nPCR ($r = 0.319$; $P < 0.001$), determined by Randerson *et al.* (5). The higher the total weekly Kt/V, the greater the DPI and the better the nutrition status. Patients with total (PD and renal) Kt/V $\geq$1.7 and preserved RRF (group I) had higher DPI and better nutrition than patients with no RRF but who managed to maintain Kt/V $\geq$1.7 by increasing PDKt/V (group II). Among patients with minimal RRF (groups II and III), a trend toward higher DPI and a better subjective global assessment score was noted with higher peritoneal clearance (group II), although this was statistically insignificant. However, this was not the result of increased peritoneal clearance but rather of the lower percentage of diabetics in group II *versus* group III (19% *versus* 39%). Indeed, DPI (1.03 $\pm$ 0.45 *versus* 1.15 $\pm$ 0.46 g/kg per d; $P = 0.05$), DCI (21.5 $\pm$ 7.6 *versus* 26.4 $\pm$ 9.0 kcal/kg per d; $P < 0.001$), and subjective global assessment score (% with normal/mild/moderate and severe malnutrition: 45/33/22 *versus* 60/25/15; $P = 0.072$) were found to be worse for diabetic patients *versus* nondiabetic patients undergoing CAPD, respectively. The significantly lower BW and height for group II compared with group III was also explained by significantly more women in group II *versus* III (59% *versus* 39%) rather than group II patients being more malnourished. Average BW was 54 $\pm$ 9 *versus* 62 $\pm$ 10 kg ($P < 0.001$), and height was 1.53 $\pm$ 0.06 *versus* 1.63 $\pm$ 0.05 m ($P < 0.001$) for women *versus* men undergoing CAPD, respectively. Indeed, after adjustment for age, gender, BW, and presence of diabetes, total weekly Kt/V and RRF remained significantly and independently associated with DPI and DCI. No association, however, was noted for PDKt/V with DPI and DCI.

Our results indicate that, although total Kt/V is important in determining DPI, RRF probably plays a more crucial role in determining actual DPI. PD dose is often increased in patients with loss of RRF to compensate for loss in Kt/V and maintain both dietary intake and nutrition status. However, an increase in PDKt/V is not independently associated with increases in DPI and DCI, which suggests that renal and peritoneal urea clearance are not equivalent in terms of their solute removal. This is consistent with previous analysis by the CANUSA study (18) and other investigations (32,33), which have shown that RRF is an important contributor to the total solute clearance in patients undergoing PD and that changes in RRF, but not those in peritoneal clearance, were significantly correlated with outcome (32,33). Studies have also noted a significant contribution of RRF to the overall nutritional status in patients undergoing dialysis (8,32), and this may be mediated mainly via a significantly higher DPI, DCI, and other nutrient intake in patients with better preserved RRF, as was demonstrated in this study.

Our findings are consistent with previous studies that have suggested that a daily DPI of at least 1 to 1.2 g/kg BW is required to maintain a positive nitrogen balance in patients undergoing CAPD (34,35). A significantly higher incidence of moderate to severe malnutrition was found among local Chinese patients with total Kt/V $<$1.7 who had a mean daily DPI of 0.99 g/kg per d, which indicates the importance of dialysis adequacy in determining DPI and, hence, nutrition status.

Other than DPI, we confirmed an independent effect of RRF on actual DCI in patients undergoing CAPD. DCI was not only significantly higher for patients with higher Kt/V but also for patients with higher RRF. Among patients with weekly Kt/V $\geq$1.7, those with RRF (group I) had a significantly higher DCI than those with no RRF (group II). Among patients with markedly diminished RRF, no difference was noted in DCI between those with Kt/V $\geq$1.7 (group II) and those with Kt/V $<$1.7 (group III), which suggests the importance of RRF but not peritoneal clearance in determining DCI and energy balance in patients undergoing CAPD. A similar finding was noted with intake of other major nutrients, including carbohydrate, fat, saturated fatty acid, monounsaturated fatty acid, polyunsaturated fatty acid, and cholesterol. It is important to note that even among the most adequately dialyzed patients with preserved RRF, DCI remained significantly lower than that recommended for normal patients undergoing PD (34), because the energy provided by peritoneal glucose absorption was not included as part of the DCI.

Previous studies have suggested a weekly Kt/V of at least 1.7 and a weekly creatinine clearance of at least 50 L to be associated with net PCR $>$0.9 g/kg of normalized body weight in average white patients undergoing CAPD (36). The National Kidney Foundation Dialysis Outcome Quality Initiative PD Working Group also noted a weekly Kt/V of $\geq$1.7 to be associated with better patient survival (37). On the other hand, the recent CANUSA study suggested a higher Kt/V to be associated with better patient outcome and that a weekly Kt/V of 2.1 is associated with an expected 2-yr survival of 78% (4). The current Dialysis Outcome Quality Initiative PD working group also recommended a minimum weekly Kt/V target of 2.0 for patients undergoing CAPD (37). In our study, however, a total weekly Kt/V of 1.7 was used as the cutoff value for adequate dialysis. This is based on previous epidemiologic studies that have shown that Asian patients undergoing CAPD achieved a better clinical outcome despite having a lower Kt/V according to the standards for white patients (3,38). Two-year patient survival was 83% in the Chinese population, compared with 78% in the CANUSA study, with an average weekly Kt/V of 1.75 *versus* 2.1 (Chinese *versus* white population, respectively) (3). As has been shown in this study, providing a total weekly Kt/V of $\geq$1.7 was able to achieve an average DPI of 1.2 g/kg per d and DCI of 26 kcal/kg per d in the Chinese patients undergoing CAPD.

In summary, our data confirm higher dietary protein, calorie, and other nutrient intake with better small-solute clearance in patients undergoing CAPD. We also demonstrate a significant and independent contribution of RRF, not only to the overall small-solute clearance but also to the actual dietary protein, calorie, and other nutrients in patients undergoing CAPD. Better small-solute clearance by the kidney may result in less uremic toxin accumulation and, hence, less impaired taste perception and better appetite. Further study is needed to define the exact mechanisms for reduced appetite and dietary intake in patients with loss of RRF.

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