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Increased Peritoneal Membrane Transport Is Associated with Decreased Patient and Technique Survival for Continuous Peritoneal Dialysis Patients

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Abstract. The objective of this study was to evaluate the association of peritoneal membrane transport with technique and patient survival. In the Canada-USA prospective cohort study of adequacy of continuous ambulatory peritoneal dialysis (CAPD), a peritoneal equilibrium test (PET) was performed approximately 1 mo after initiation of dialysis; patients were defined as high (H), high average (HA), low average (LA), and low (L) transporters. The Cox proportional hazards method evaluated the association of technique and patient survival with independent variables (demographic and clinical variables, nutrition, adequacy, and transport status). Among 606 patients evaluated by PET, there were 41 L, 192 LA, 280 HA, and 93 H. The 2-yr technique survival probabilities were 94, 76, 72, and 68% for L, LA, HA, and H, respectively ($P = 0.04$). The 2-yr patient survival probabilities were 91, 80, 72, and 71% for L, LA, HA, and H, respectively ($P = 0.11$). The 2-yr probabilities of both patient and technique survival were 86, 61, 52, and 48% for L, LA, HA, and H, respectively ($P = 0.006$). The relative risk of either technique failure or death, compared to L, was 2.54 for LA, 3.39 for HA, and 4.00 for H. The mean drain volumes (liters) in the PET were 2.53, 2.45, 2.33, and 2.16 for L, LA, HA, and H, respectively ($P < 0.001$). After 1 mo CAPD treatment, the mean 24-h drain volumes (liters) were 9.38, 8.93, 8.59, and 8.22 for L, LA, HA, and H, respectively ($P < 0.001$); the mean 24-h peritoneal albumin losses (g) were 3.1, 3.9, 4.3, and 5.6 for L, LA, HA, and H, respectively ($P < 0.001$). The mean serum albumin values (g/L) were 37.8, 36.2, 33.8, and 32.8 for L, LA, HA, and H, respectively ($P < 0.001$). Among CAPD patients, higher peritoneal transport is associated with increased risk of either technique failure or death. The decreased drain volume, increased albumin loss, and decreased serum albumin concentration suggest volume overload and malnutrition as mechanisms. Use of nocturnal cycling peritoneal dialysis should be considered in H and HA transporters.

The association of peritoneal membrane transport characteristics with patient and technique survival among patients treated with continuous ambulatory peritoneal dialysis (CAPD) is uncertain. Increased transport may be associated with increased removal of uremic solutes and thereby improve patient and technique survival. On the other hand, increased loss of proteins may induce malnutrition (1), which is associated with worse patient survival (2). Rapid absorption of glucose from the dialysate may decrease appetite and contribute to malnutrition (3), may be associated with an atherogenic lipid profile (4), and may be responsible for fluid overload secondary to decreased net ultrafiltration. Reduced drain volumes could reduce small solute clearances despite rapid equilibration.

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In the Canada-USA (CANUSA) study of the adequacy of peritoneal dialysis (5), a peritoneal equilibration test (PET) was performed at enrollment and at six monthly intervals for 606 patients. We report the association of membrane transport type with patient and technique survival while controlling for demographic and clinical variables, nutritional status, and adequacy of dialysis.

Materials and Methods

The CANUSA study of the adequacy of peritoneal dialysis (5) is a multicenter prospective cohort study of incident CAPD patients in North America. The 14 clinical centers were: Victoria General Hospital (Halifax, Nova Scotia), Toronto Western and General Divisions of The Toronto Hospital (Toronto, Ontario), St. Joseph's Hospital (Hamilton, Ontario), Credit Valley Hospital (Mississauga, Ontario), Ottawa Civic Hospital (Ottawa, Ontario), St. Boniface Hospital (Winnipeg, Manitoba), Foothills Hospital (Calgary, Alberta), Medical College of Wisconsin (Milwaukee, Wisconsin), University of Missouri Medical Centre (Columbia, Missouri), Ottawa General Hospital (Ottawa, Ontario), Lankenau Hospital (Philadelphia, Pennsylvania), University of Alberta Hospital (Edmonton, Alberta), and Medical College of Georgia (Augusta, Georgia). The coordinating center was

the Department of Clinical Epidemiology and Biostatistics, McMaster University, Hamilton.

All patients starting peritoneal dialysis for the first time between September 1, 1990, and December 31, 1992, were eligible for the study. Exclusion criteria were: (*1*) unlikely to survive 6 mo; (*2*) elective living donor transplant within 6 mo; (*3*) planned to move from the study center within 6 mo; (*4*) positive hepatitis B or HIV serology; (*5*) active systemic inflammatory disease; and (*6*) failure to sign informed consent. The dialysis prescription was according to the individual patient's physician.

The demographic data recorded at enrollment included dialysis center, race, gender, age, functional status (6), diabetic status, and history of cardiovascular disease (CVD). In the initial CANUSA study, diabetic patients receiving insulin were considered insulin-dependent (5). For this study, diabetes was reclassified as type I or II, using a validated algorithm (7). CVD was defined as myocardial infarction, angina, amputation for vascular disease, or class III/IV congestive heart failure.

Estimates of nutritional status, adequacy of dialysis, and membrane transport status were obtained at the completion of CAPD training (approximately 1 mo after initiation of dialysis) and were considered the baseline values. These estimates were repeated every 6 mo thereafter. If there was an acute medical problem, the evaluation occurred 1 mo after resolution of the problem.

The estimates of nutritional status were: serum albumin concentration by the bromcresol green method and subjective global assessment (SGA) of nutritional status by a modification (5) of the method of Baker *et al.* (8). The lean body mass (LBM) was estimated from creatinine kinetics (9) and normalized by body weight. Protein catabolic rate (PCR) according to the Randerson method (10) was normalized (NPCR) by standard body weight ($V/0.58$), where V is total body water according to the Watson nomogram (11).

Adequacy of dialysis was estimated by measurement of total weekly urea clearance (Kt) normalized to total body water (V) and total weekly creatinine clearance (C_{Cr}) per 1.73 m^2 body surface area. Peritoneal Kt was estimated from a 24-h dialysate urea and the serum urea concentration at the completion of the collection. Renal Kt was estimated from the concurrent 24-h urine urea and serum urea at the completion of the collection. Peritoneal C_{Cr} was estimated from a 24-h dialysate creatinine and the serum creatinine concentration at the conclusion of the collection. Dialysate creatinine concentration was corrected, where necessary, for glucose interference, using a correction factor determined in each laboratory (12). The renal contribution to creatinine clearance attributed to glomerular filtration and excluding tubular secretion was estimated from the average of urea and creatinine clearance (13). This approximates GFR as determined by inulin clearance (14).

The nonfasting serum cholesterol concentration was determined at the baseline assessment. To evaluate changes in serum albumin concentration, these values were determined at six monthly intervals. The 24-h dialysate protein and albumin excretions were determined at baseline.

Peritoneal membrane transport was evaluated by a PET. Either a standard PET (15) or a fast PET (16) was performed with the 4-h dialysate/plasma creatinine ratio (D/P Cr) used to classify a patient as low (L), low average (LA), high average (HA), or high (H) according to Twardowski *et al.* (15).

The distribution of demographic and baseline clinical factors among the ordered peritoneal transport groups was analyzed by the Mantel–Haenzel test for linear trend. The mean responses among groups with respect to adequacy of dialysis, nutritional status, serum cholesterol, and 24-h dialysate excretions of albumin and protein were compared by analysis of covariance (ANCOVA). This technique adjusts the mean responses for differences in demography and baseline clinical variables. The Pearson correlations between baseline serum albumin with 24-h dialysate protein and albumin excretion were determined.

Statistical Analyses

The clinical outcomes evaluated were mortality and technique failure. The latter was defined as permanent transfer to hemodialysis or to conventional, three-times-weekly intermittent peritoneal dialysis. Statistical analyses of patient mortality and technique failure used Andersen and Gill's extension (17) to the Cox proportional hazards model (18), with estimates of nutritional status and adequacy of dialysis as time-dependent covariates (19,20). Events (*e.g.*, death or technique failure) were attributed to the level of nutrition or adequacy of dialysis recorded at the six monthly evaluations before the event. Transplantation, recovery of renal function, and loss to follow-up were censored observations for the patient survival. For technique survival, death was an additional censored observation. All baseline demographic and clinical variables were entered, as well as the baseline serum albumin concentration. Backward elimination removed nonsignificant variables. Two estimates of adequacy of dialysis (C_{Cr} and Kt/V) were entered separately. Each was divided into that derived from residual renal function and that provided by peritoneal clearance. The baseline transport status was then entered by transport category and as a continuous variable, D/P creatinine. The SGA was entered as a time-dependent clinical estimate of nutritional status. All variables in the multivariate model were examined with respect to statistical interaction. The validity of the proportional hazards assumption was considered for all variables remaining in the final models by examining the Schoenfeld residuals (21). Survival curves were constructed by the Kaplan–Meier method (22) and compared by the log-rank test.

Results

Among the 680 patients enrolled in the CANUSA study, 606 had a PET performed at enrollment. Descriptive data are shown in Table 1. There were 41 (6.8%) with low (L) transport, 192 (31.7%) with low average (LA) transport, 280 (46.2%) with high average (HA) transport, and 93 (15.3%) with high (H) transport. The mean ages in the L, LA, HA, and H transport categories were 50.5, 52.9, 56.4, and 56.0 yr, and the proportion of men ranged from 48.8% in the L transport group to 68.8% in the H transport group. The Mantel–Haenzel test for linear trend showed statistically significant differences among transport groups with respect to age, gender, and both type I and type II diabetes mellitus ($P < 0.05$ for each comparison). There was an increase in mean age, a greater proportion of men, and a greater proportion of patients with diabetes mellitus with higher peritoneal membrane transport according to PET. There was no significant difference among groups with respect to the proportion of patients with a history of CVD.

The baseline nutritional data by transport status is shown in Table 2. There is a significant difference in serum albumin concentration, with values decreasing from 37.8 to 32.8 from L to H ($P < 0.001$; ANCOVA). There were no differences among transport groups with respect to baseline SGA, percentage LBM, or NPCR ($P > 0.05$).

The baseline residual renal function and peritoneal clear-

Table 1. Demographic and clinical variables by PET status[a]

Group	*n*	Age (SD)[b]	Gender[b] (% Male)	Race (% Caucasian)	Diabetes[b]		CVD (%)
					(% I)	(% II)	
L	41	50.5 (15.7)	48.8	85.4	9.8	17.1	24.2
LA	192	52.9 (16.3)	56.8	78.6	9.4	13.0	39.1
HA	280	56.2 (14.5)	61.1	82.1	17.5	18.2	35.4
H	93	56.0 (14.5)	68.8	81.7	14.0	19.4	32.3
Mean	606	54.8	60.0	81.2	13.9	16.7	35.3

[a] PET, peritoneal equilibrium test; I, type I diabetes mellitus; II, type II diabetes mellitus; CVD, cardiovascular disease; L, low; LA, low average; HA, high average; H, high.
[b] $P < 0.05$ by Mantel–Haenzel test for linear trend.

Table 2. Nutritional variables by PET status[a]

Group	S.Alb[b] g/L (SD)	SGA Units (SD)	LBM % (SD)	NPCR g/kg (SD)
L	37.8 (5.3)	5.5 (1.5)	62.9 (17.3)	1.05 (0.25)
LA	36.2 (4.9)	5.2 (1.4)	64.0 (15.9)	1.05 (0.26)
HA	33.8 (5.2)	5.2 (1.5)	61.1 (13.7)	1.03 (0.28)
H	32.8 (4.9)	5.1 (1.2)	62.0 (11.3)	1.02 (0.28)
Mean	34.7	5.2	62.3	1.04

[a] S.alb, serum albumin; SGA, subjective global assessment; LBM, lean body mass; NPCR, normalized protein catabolic rate. Other abbreviations as in Table 1.
[b] $P < 0.001$ by Mantel–Haenzel test for linear trend.

Table 3. Adequacy of dialysis and residual renal function by transport status[a]

Group	Weekly Renal Kt/V (SD)	Weekly Peritoneal Kt/V (SD)	Weekly Renal C_{Cr} L/wk (SD)	Weekly Peritoneal C_{Cr}[b] L/wk (SD)
L	0.58 (0.45)	1.66 (0.40)	34.7 (30.0)	36.6 (9.3)
LA	0.66 (0.58)	1.68 (0.40)	38.0 (32.7)	41.8 (9.7)
HA	0.72 (0.51)	1.69 (0.85)	38.3 (25.9)	45.8 (8.0)
H	0.78 (0.64)	1.58 (0.36)	40.2 (25.2)	48.4 (9.4)
Mean	0.70	1.67	38.2	44.3

[a] C_{Cr}, creatinine clearance rate. Other abbreviations as in Table 1.
[b] $P < 0.001$ by Mantel–Haenzel test for linear trend.

ances of urea and creatinine are shown in Table 3. Although the mean weekly renal Kt/V and C_{Cr} are greater with higher transport status, neither is statistically significant ($P < 0.05$ in each instance). There is no difference among groups with respect to baseline peritoneal Kt/V, whereas there is a significant difference in mean weekly peritoneal creatinine clearance, ranging from 36.6 in L to 48.4 in H transporters ($P < 0.001$). The mean time from initiation of peritoneal dialysis to performance of the PET was 34.2, 40.9, 41.1, and 43.5 d for the L, LA, HA, and H transport groups, respectively ($P = 0.568$).

There was no difference in mean D/P creatinine by gender; 0.67 for women and 0.70 for men ($P > 0.05$). Patients with type I and II diabetes mellitus had mean values of 0.71 and 0.70 compared with 0.68 for those without diabetes ($P > 0.05$). There was no difference between those with and without a history of CVD (0.69 for each group).

The 2-yr probability of transplantation was higher among those with L and LA transport (42 and 34%, respectively) than for those with HA and H transport (18 and 25%, respectively) ($P = 0.015$; log-rank).

The 2-yr patient survival probabilities were 90.9% for L, 80.4% for LA, 72.4% for HA, and 70.5% for H (Figure 1) ($P = 0.111$). The 2-yr probabilities of technique survival were 94.4% for L, 75.7% for LA, 71.6% for H, and 68.1% for HA (Figure 2) ($P = 0.036$). The combined probabilities of either death or technique failure are shown in Figure 3 (85.8% for L, 60.9% for LA, 51.8% for HA, and 48.0% for H; $P = 0.006$).

The relative risk (RR) of death, technique failure, or either

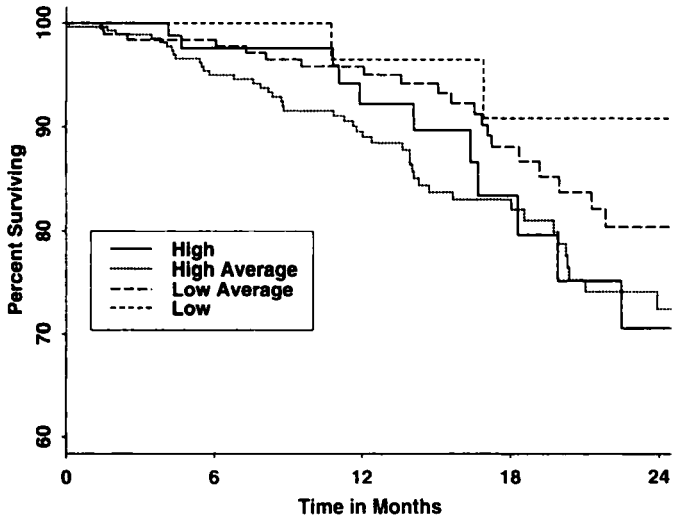

Figure 1. Probability of patient survival according to peritoneal membrane transport characteristic.

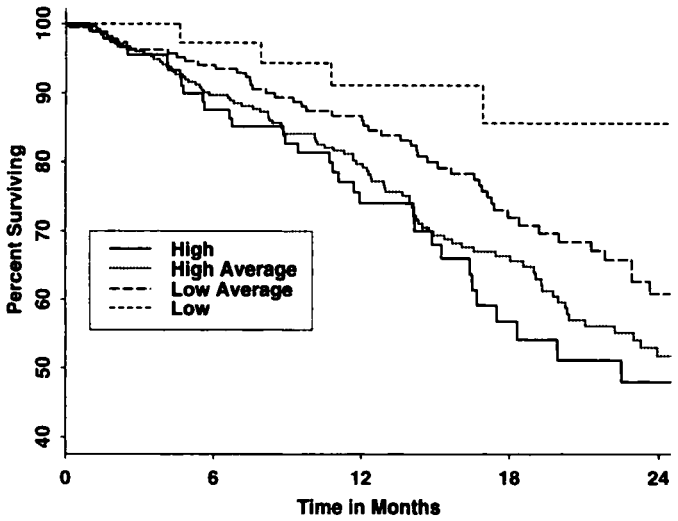

Figure 3. Probability of *combined* patient and technique survival according to peritoneal membrane transport characteristic.

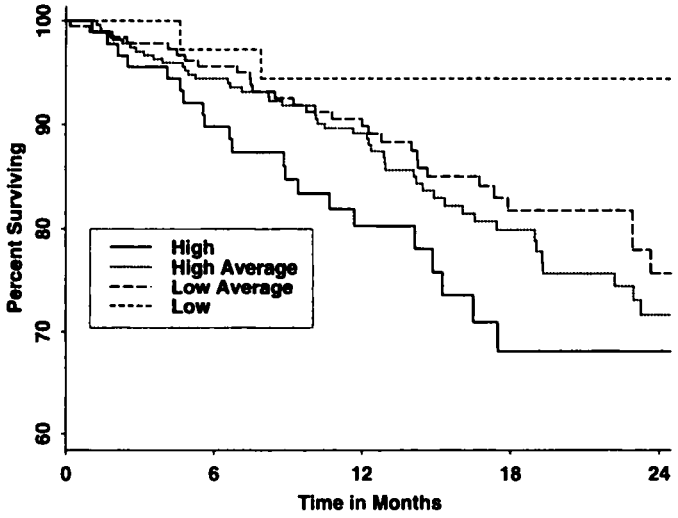

Figure 2. Probability of technique survival according to peritoneal membrane transport characteristic.

Table 4. Relative risk of death, technique failure, or either according to peritoneal transport[a]

Group	Death	Transfer to HD or IPD	Either Death or Transfer
L	1.00	1.00	1.00
LA	1.60	3.26	2.54
HA	2.30	4.04	3.39
H	1.94	5.82	4.00

[a] HD, hemodialysis; IPD, intermittent peritoneal dialysis. Other abbreviations as in Table 1.

Table 5. Relative risk of either technique failure or death[a]

Variable	RR	95% CI
Age (↑ 1 yr)	1.01	(1.00 to 1.02)
CVD	1.60	(1.18 to 2.17)
Diabetes mellitus[b]	1.19	(0.87 to 1.63)
Albumin (↑ 1 g/L)	0.97	(0.94 to 0.99)
Transport		
LA	2.54	(0.91 to 7.10)
HA	3.39	(1.23 to 9.32)
H	4.00	(1.40 to 11.48)
C_{Cr} (↑ 5 L/wk)	0.92	(0.89 to 0.96)
SGA (↑ 1 U)	0.79	(0.72 to 0.87)

[a] C_{Cr} as estimate of adequacy. RR, relative risk; 95% CI, 95% confidence interval. Other abbreviations as in Tables 1 and 2.
[b] Combination of types I and II.

was determined using the Cox proportional hazards model. The data summarized in Table 4 used C_{Cr} as the estimate of adequacy. The RR of death increased progressively from L to LA to HA (1.00 to 1.60 to 2.30) and then decreased for the H group (RR, 1.94). The RR of technique failure increased from 3.26 for LA to 4.04 for HA to 5.82 for H. The RR of either technique failure or death increased progressively with increased transport category (1.00 to 2.54 to 3.39 to 4.00). The results were not different when Kt/V was used as the estimate of adequacy.

The full Cox proportional hazards model analysis for the combined outcome of either technique failure or death is shown in Table 5, using C_{Cr} as the estimate of adequacy of dialysis, and in Table 6, using Kt/V as the estimate. For C_{Cr} (Table 5), the RR of either technique failure or death is shown with the 95% confidence limits (95% CI). The RR increases by 1.0% for a 1 yr greater age and 60% for those with CVD. The RR decreases by 3% for a 1 g/L increased serum albumin; 8% for a 5 L/wk greater total C_{Cr}; and 21% for a 1 U increase in

Table 6. Relative risk of either technique failure or death[a]

Variable	RR	95% CI
Age (↑ 1 yr)	1.01	(1.00 to 1.02)
CVD	1.56	(1.16 to 2.11)
Diabetes mellitus[b]	1.14	(0.83 to 1.56)
Albumin (↑ g/L)	0.96	(0.93 to 0.99)
Transport		
LA	2.25	(0.81 to 6.25)
HA	2.78	(1.02 to 7.59)
H	3.01	(1.06 to 8.56)
Kt/V (↑ 0.1/wk)	0.96	(0.94 to 0.99)
SGA (↑ 1 U)	0.80	(0.73 to 0.87)

[a] Kt/V as estimate of adequacy. Abbreviations as in Tables 1, 2, and 5.
[b] Combination of types I and II.

Table 7. Dialysate protein and albumin losses at baseline by transport group

Group	*n*	Protein[a] g/24 h (SD)	*n*	Albumin[a] g/24 h (SD)
L	40	5.29 (2.22)	29	3.09 (1.40)
LA	191	6.19 (2.11)	134	3.86 (1.57)
HA	280	7.10 (2.56)	177	4.27 (1.81)
H	93	8.77 (4.05)	54	5.61 (3.17)

[a] $P < 0.001$ by ANCOVA.

the SGA. There was no significant association with diabetes mellitus (type I and II combined). Compared to L, those with LA, HA, and H transport had a RR of either death or technique failure of 2.54, 3.39, and 4.00, respectively. A similar pattern is seen when Kt/V is used as the estimate of adequacy of dialysis (Table 6). When transport status is entered as a continuous variable, the RR of either technique failure or death is 1.19 (95% CI, 1.05 to 1.34) for a 0.1 greater D/P creatinine. There were no statistical interactions among predictor variables in this multivariate model.

There were 83 deaths and 108 technique failures. The majority of deaths were attributed to cardiovascular, cerebrovascular, or other vascular events (61 of 83); many of the technique failures were unspecified (43 of 108). Infection accounted for four deaths and 31 technique failures. Inadequate fluid removal was cited as the reason for technique failure in 1 of 32 among those with L and LA transport compared to 6 of 76 among those with HA and H transport. The mean drain volumes in the PET were 2.53, 2.45, 2.33, and 2.16 L for the L, LA, HA, and H transport groups, respectively ($P < 0.001$; ANCOVA). The mean 24-h drain volumes after 1 mo CAPD treatment were 9.38, 8.93, 8.59, and 8.22 L for L, LA, HA, and H transport groups, respectively ($P < 0.001$; ANCOVA).

Linear regression indicates an association, at the 1-mo evaluation, between higher D/P Cr and lower serum albumin concentration ($r = 0.30$; $P < 0.001$). However, a smoothed best-fit function (23) demonstrates a nonlinear relationship, with a change in the slope of the line at a serum albumin concentration of 35 g/L and a D/P of 0.7. The decrease in serum albumin per unit increase in D/P is greater at D/P > 0.7 than below this value. There is no statistically significant relationship of D/P creatinine with age, weight, or body surface area. The baseline (1-mo evaluation) 24-h dialysate protein and albumin excretions are shown in Table 7. The 24-h protein loss increased from 5.29 g in the L group to 8.77 g in the H group, whereas the albumin loss increased from 3.09 to 5.61 g between L and H transport groups ($P < 0.001$ for each; ANCOVA). The correlations of serum albumin with 24-h dialysate protein and albumin were $r = -0.01$ in each case. The correlation between NPCR and serum albumin was 0.24 ($P = 0.054$). The nonfasting serum cholesterol values were 4.16, 4.16, 4.30, and 4.29 mmol/L in the L, LA, HA, and H transport groups, respectively ($P = 0.57$).

For patients treated with peritoneal dialysis for 18 mo, the serum albumin concentrations are shown in Table 8. The values are lower in higher transport groups at the 1-mo (baseline) evaluation, and the differences do not change over time. For those same patients, the NPCR values are shown in Table 9. There is no difference among transport groups or over time.

Discussion

The finding of a higher RR of either technique failure or death among CAPD patients with higher peritoneal transport appears to contradict the suggestion that increased clearance of uremic toxins should produce better patient and technique survival, in that these patients would be expected to have the highest clearance. Indeed, peritoneal creatinine clearances were higher with increased transport category. However, peritoneal Kt/V increased from L to LA to LA, but decreased in the H transport group, probably secondary to low drain volumes.

High-transport CAPD patients have worse nutritional status than those with low transport membranes (1). A suggested mechanism is that high transporters have greater glucose absorption with inhibition of appetite and greater loss of protein in the dialysate leading to malnutrition and that these patients might be better suited to more frequent cycles with shorter dwell time rather than CAPD. A similar suggestion was made by Heaf (3), who reported increased clinical morbidity (fatigue, nausea, pain, and edema) among patients with increased peritoneal transport.

The data in Table 1 showed a statistically significantly increased mean age, proportion of men, and patients with type I and type II diabetes mellitus with increased transport group. There were no differences with respect to race or history of CVD. The multivariate statistical analyses controlled these variables, and they did not explain the increased RR of technique failure, death, or both associated with increased membrane transport.

There is a decreased mean serum albumin concentration with increased transport category but no difference in other estimates of nutritional status (Table 2). Nolph *et al.* (1) reported decreased LBM and lower NPCR among those with

Table 8. Serum albumin concentration for patients treated for 18 mo

Group	*n*	Baseline g/L (SD)	6 mo g/L (SD)	12 mo g/L (SD)	18 mo g/L (SD)
L	11	37.7 (6.5)	37.7 (6.5)	37.7 (6.5)	37.7 (6.5)
LA	51	36.2 (5.2)	36.0 (5.9)	36.4 (5.6)	36.2 (5.8)
HA	70	33.1 (4.8)	33.1 (4.7)	33.0 (4.8)	33.1 (4.8)
H	16	33.2 (5.0)	33.4 (5.1)	33.9 (4.5)	33.2 (5.0)
P value		0.003	0.005	0.001	0.003

Table 9. Normalized protein catabolic rate for patients treated for 18 mo

Group	*n*	Baseline g/kg (SD)	6 mo g/kg (SD)	12 mo g/kg (SD)	18 mo g/kg (SD)
L	11	1.12 (0.24)	1.14 (0.37)	0.96 (0.25)	1.02 (0.28)
LA	51	1.03 (0.29)	1.03 (0.27)	0.94 (0.19)	0.96 (0.24)
HA	70	1.03 (0.20)	1.03 (0.27)	0.99 (0.22)	0.91 (0.21)
H	16	1.02 (0.26)	0.91 (0.13)	1.03 (0.17)	0.92 (0.21)
P value		0.68	0.17	0.44	0.36

higher membrane transport. In the current study, these nutritional data were obtained approximately 1 mo after initiation of CAPD therapy, whereas the patients studied by Nolph *et al.* (1) had the nutritional assessment performed 10 to 32 mo later. We determined the mean serum albumin concentration in each transport group at baseline, 6 mo, 12 mo, and 18 mo for those patients treated for 18 mo. These data suggest that the changes observed at 10 to 32 mo by Nolph *et al.* (1) were present very early (34 to 44 d) in the course of CAPD treatment and changed little over 18 mo. Among the several explanations for a decrease in serum albumin concentration are an increased loss of protein in the dialysate and volume expansion due to decreased ultrafiltration. These explanations are consistent with the data shown in Table 7 and the finding of decreased drain volumes with higher transport.

The Cox analysis reported in Table 4 shows the RR of death increasing from L to LA and HA, and then decreasing for those with H transport. On the other hand, the RR of technique failure increases dramatically with increased transport, and there is a similar finding when technique failure and death are combined clinical outcomes. The decreased RR of death in the H compared with the HA transport group is probably due to biased censoring. The transfer to hemodialysis removes those at highest risk for death, thereby leaving a relatively better risk group on CAPD. The probability of transplantation was higher for those with L and LA than for those with H and HA transport.

One interpretation is that patients with LA and LA transport were healthier than those with H and HA transport and were more likely to receive a renal transplant. The baseline nutritional estimates (SGA, NPCR, and LBM) do not support this suggestion. On the other hand, those with lower peritoneal membrane transport tend to be younger and nondiabetic. These variables would suggest a healthier population. If healthier patients were more likely to receive a renal transplant, transport groups with the highest rate would, by censoring transplanted patients, have an increased proportion of less healthy patients remaining at risk. This censoring bias should favor a better clinical outcome in transport groups with a lower transplant rate.

These data suggest that increased peritoneal membrane transport among CAPD patients is associated with an increased RR of either technique failure or death. The multivariate Cox proportional hazards model indicates that this risk is independent of age, comorbidity, and delivered dialysis dose as estimated by Kt/V and C_{Cr}. Wu *et al.* (24) reported a RR of 2.0 for technique failure or death among patients with a 4-h D/P creatinine >0.82. Davies *et al.* (25) recently reported a 3-yr patient survival probability of 70.5% for H transporters compared with >85% for L, LA, and H.

The PET transport status is determined from the ratio of dialysate to plasma creatinine. The concern about statistical linkage to another variable (C_{Cr}) in the multivariate analysis was addressed by removing C_{Cr} and then transport status from the Cox analysis. When C_{Cr} was removed from the model, there was no change in the RR of technique failure and/or death associated with transport status. Similarly, when transport status was removed from the model, the RR associated with C_{Cr} was unchanged. The multivariate analysis, using Kt/V as the estimate of adequacy, showed similar results.

The mechanism is speculative. Low serum albumin, a variable associated with an increased risk of death, is present in those with higher peritoneal membrane transport within the first 34 to 44 d of therapy. There is greater albumin and total protein loss among those with increased transport, and this might partly explain the decreased serum albumin. The decreased drain volumes noted both on PET and 24-h collections may produce volume expansion and dilutional hypoalbuminemia. Protein intake, as estimated from the NPCR, is not dif-

ferent among transport groups at baseline and decreases at similar rates over time within each group (Table 9).

The increased probability of technique failure or death with higher peritoneal membrane transport among patients treated with conventional CAPD makes this specific modality less attractive for these patients. Increased glucose absorption can lead to decreased ultrafiltration and volume expansion. The low serum albumin is probably due to increased peritoneal losses of protein and dilution by the absorbed dialysate. The role of the absorbed glucose in the pathogenesis of increased RR of death is uncertain. The use of short-cycle techniques via an automated cycler could enhance ultrafiltration with less glucose absorption (1,15). However, protein losses per day in dialysate would be similar (26). The development of alternative osmotic agents should be a research priority, and the efficacy of amino acid solutions should be documented in future studies.

In summary, these findings show that higher transport status is associated with an increased risk for transfer from CAPD and/or death. There are lower serum albumin concentrations even at 1 mo into CAPD (for reasons that need further study), and there are lower serum albumin concentrations during the first 2 yr of CAPD. Higher protein losses without increased protein intakes compared to other transport groups most likely contribute. High transporters should be encouraged to consume more protein and to reduce the need for hypertonic exchanges by curtailing sodium and water intake. Early transfer to short-cycle techniques using an automated cycler or to hemodialysis should be considered if any sign of malnutrition appears.

Appendix

CANUSA Peritoneal Dialysis Study Group

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