http://www.kidney-international.org

New insight of amino acid-based dialysis solutions

MS Park[1], SR Choi[2], YS Song[3], SY Yoon[4], SY Lee[5] and DS Han[2]

[1]Baxter Asia Pacific Renal, Seoul, Korea; [2]Division of Nephrology, Department of Internal Medicine, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea; [3]Department of Internal Medicine, Hanlym University, Seoul, Korea; [4]Department of Internal Medicine, Kwandong University, Seoul, Korea and [5]Department of Applied Mathematics, Sejong University, Seoul, Korea

Malnutrition is a major complication of peritoneal dialysis (PD) and is associated with increased morbidity and mortality. Daily losses of proteins and amino acids (AAs) into dialysate contribute to this problem. Previous metabolic balance study demonstrated that treatment with 1.1% AA-based dialysis solution is safe and may improve protein malnutrition in continuous ambulatory peritoneal dialysis (CAPD) patients ingesting low protein intake. Other prospective studies also showed that AA solution can provide nutritional benefit for malnourished PD patients resulting in a significant improvement in some biochemical and/or anthropometric nutritional parameters. However, there are other studies showing no particular improvement in nutritional parameters after long-term use of AA solution. This may be related to the differences in the study design, sample size, methods used to assess nutritional status, and other factors such as dietary intake and comorbidities of study subjects. Published data will be reviewed to further emphasize the nutritional benefit of long-term use of AA solution in malnourished PD patients along with a brief discussion on the various reasons that may partly explain the different study results. We will also present the results of a longitudinal observational study evaluating changes in nutritional parameters following use of one exchange of 1.1% AA solution in malnourished Korean PD patients. A significant improvement of somatic protein status such as lean body mass (LBM) and hand grip strength was observed. No significant change in serum albumin level was noted. Patients with a positive estimated coefficient for LBM in the fitted regression model to the repeated observations over 1 year were classified as responders and patients with neutral or negative coefficient were considered as non-responders. Thirty-one out of 43 malnourished patients (72%) showed nutritional benefit based on the change of LBM. Hand grip strength and back lift strength were significantly higher in responders at baseline. Other baseline parameters did not differ between the two groups.

Kidney International (2006) **70,** S110–S114. doi:10.1038/sj.ki.5001925

KEYWORDS: peritoneal dialysis; amino acids; non-glucose osmotic agents

Correspondence: *DS Han, Division of Nephrology, Department of Internal Medicine, Severance Hospital, Yonsei University College of Medicine, 134 Shinchon-dong, Seodaemun-gu, Seoul, 120-752, Korea.*
E-mail: dshan@yumc.yonsei.ac.kr

Protein energy malnutrition is common in patients undergoing peritoneal dialysis and is associated with increased morbidity and mortality.[1–5] Poor dietary intake and loss of nutrients into the dialysate are some of etiologic factors known to contribute to malnutrition. Patients on PD are reported to lose 3–4 g/day amino acids (AAs) and 4–15 g/day of protein.[6] One exchange with a 1.1% AA dialysis solution is sufficient to compensate for these losses and to improve nitrogen balance.[7]

Malnourished patients benefit from AA dialysis solutions through peritoneal AA uptake[7–13] and increased protein anabolism associated with improvement in some biochemical and/or anthropometric nutritional parameters.[7,14] However, this nutritional benefit from AA solutions was not uniformly observed in long-term studies. This may be related to study design, sample size, different methods used to assess nutritional status, and other factors influencing nutritional status such as adequacy of dialysis and inflammation.

In this paper, existing data will be reviewed to delineate the current status of the potential nutritional benefits of AA solutions. We will also present a preliminary study carried out to ascertain potential factors influencing nutritional status following AA use in malnourished PD patients.

CHARACTERISTICS OF AA SOLUTIONS AND PERITONEAL TRANSPORT

PD patients are reported to lose 3–4 g/day of AAs and 4–15 g/day of proteins.[6] AAs were used to supplement theses losses to maintain a positive nitrogen balance. The amount of AA absorbed after 6 h of dwell time with a 1.1% AA solution was $78.8 \pm 8\%$ (approximately 16 g), which was much greater than the peritoneal loss of AA after 6 h dwell time with conventional glucose solutions (0.7 ± 0.1 g of total AA).[15]

Commercially available 1.1% AA solution (Nutrineal, Baxter Healthcare Corporation) was designed to meet the nutritional requirements of uremic patients.[17] Peritoneal ultrafiltration profile and transport characteristics of this solution are similar to those of a 1.5% dextrose solution.[15,16]

NUTRITIONAL MARKERS INCLUDING BIOCHEMICAL SURROGATE MARKERS

No single measure provides a comprehensive indication of nutritional status. Measures of dietary intake, visceral and

somatic protein stores, body composition, and functional status identify different aspects of nutritional status. The National Kidney Foundation-Kidney Disease Outcome Quality Initiative (NKF-DOQI) Nutrition Practice Guidelines suggest that nutritional status in maintenance dialysis patients be routinely assessed using serum albumin level, percent usual body weight, percent standard body weight, subjective global assessment (SGA), dietary interviews/diaries, and normalized protein equivalent of total nitrogen appearance.[18] Serum levels of creatinine, cholesterol, total protein, albumin, prealbumin, insulin-like growth factor-1, and transferrin are commonly used biochemical surrogate markers. Serum albumin level is a valid and clinically useful measure of protein-energy nutritional status in maintenance dialysis patients and stabilized serum albumin is a measure of visceral protein pool size. However, serum albumin is also influenced by liver function, peritoneal loss, and/or, inflammatory status.[19] Acute or chronic inflammation limits the specificity of serum albumin as a nutritional marker.

Anthropometric measurements such as percent usual body weight, percent standard body weight, body mass index, skin fold thickness, and mid-arm circumference are valid and clinically useful indicators of protein energy nutritional status in maintenance dialysis patients. Normalized protein equivalent of total nitrogen appearance is used as an indicator of net protein degradation and protein intake. SGA is a simple, valid, and clinically useful tool to measure the global nutrition status of maintenance dialysis patients. A higher SGA score has been associated with a lower relative risk of death and fewer hospitalized days per year.[20] Table 1 shows recommended measures for monitoring nutritional status of maintenance dialysis patients.[18]

NUTRITIONAL EFFECTS OF AA SOLUTION

Several studies have shown that AA solutions provide a nutritional benefit at least in the short term.[7,12,21,22] Improvement in protein nutrition with AA-based dialysate was clearly demonstrated in a metabolic balance study of malnourished patients on continuous ambulatory peritoneal dialysis (CAPD) with low protein intake.[7] At baseline, patients were in neutral nitrogen balance and net protein anabolism was positive as determined from ^{15}N-glycine studies. After commencing intraperitoneal AA therapy, nitrogen balance became significantly positive, net protein anabolism increased significantly, fasting morning plasma AA pattern became more normal, and serum total protein and transferrin concentrations rose. Patients generally tolerated the treatment well, although some patients developed mild metabolic acidemia. Skeletal muscle AA uptake was increased after 6 weeks use of a 1.1% AA solution both in the fasting state and during insulin stimulation in 10 stable non-diabetic CAPD patients.[21]

A prospective randomized study of a 1.1% AA solution for 3 months in malnourished CAPD patients showed an increase in serum insulin-like growth factor-1 level and significant decreases in serum potassium and inorganic phosphorus levels, indicating a general anabolic response.[12] In patients with baseline albumin levels less than 3.5 g/dl, patients using the AA solution showed increases in albumin, transferrin, and prealbumin levels relative to baseline values, whereas these serum protein levels were unchanged with glucose solutions.

In an acute ^{3}H-phenylalanine kinetic study,[23] it was reported that muscle protein synthesis increased by 20% during the use of AA solution. This increase was related to a significant increase in total arterial AA level and a reduced AA release from muscle. In the same study, a 20%

Table 1 | Recommended measures for monitoring nutritional status of maintenance dialysis patients[18]

Category	Measure	Minimum frequency of measurement
Measurements that should be performed routinely in all patients	Predialysis or stabilized serum albumin	Monthly
	Percent of usual post-dialysis (MHD) or post-drain (CPD) body weight	Monthly
	Percent of standard (NHANES II) body weight	Every 4 months
	SGA	Every 6 months
	Dietary interview and/or diary	Every 6 months
	nPNA	Monthly MHD; every 3–4 months CPD
Measures that can be useful to confirm or extend the data obtained from the measures in Category I	Predialysis or stabilized serum pre-albumin	As needed
	Skin fold thickness	As needed
	Midarm muscle area, circumference or diameter	As needed
	SGA	As needed
	Dual energy X-ray absorptiometry	As needed
Clinically useful measures, which, if low, might suggest the need for a more rigorous examination of protein-energy nutrition status	Predialysis or stabilized serum	
	Creatinine	As needed
	Urea nitrogen	As needed
	Cholesterol	As needed
	Creatinine index	As needed

CPD, continuous peritoneal dialysis; nPNA, normalized protein nitrogen appearance; NHANES, National Health and Nutrition Examination Survey; SGA, subjective global assessment.

decrease in muscle protein synthesis, a 20–25% decrease in arterial AA level, a persistent negative net protein balance, and a decrease in the efficiency of muscle protein turnover were found during PD with glucose solutions alone. A short-term use of AA solution was also effective in improving net protein balance and converting nitrogen balance from negative to positive in patients on automated peritoneal dialysis.[14]

Six-month use of AA solution showed a trend towards improvement in mid-arm muscle circumference and a significant increase in serum albumin level in patients with serum albumin less than 30 g/l.[24] AA solution improved oxidative phosphorylation of muscle during exercise and recovery in nutritionally unselected stable PD patients.[25] However, there are other studies showing no improvement in nutritional parameters after 6 months use of AA solution in well-nourished CAPD patients despite increased serum concentration of AA[26] or no change in serum albumin level in stable CAPD patients.[27]

A 3-year prospective randomized study in malnourished CAPD patients showed that biochemical nutritional parameters including albumin and cholesterol level remained stable or increased in patients using an AA solution once daily, but decreased in patients with conventional dextrose solutions.[28]

POTENTIAL FACTORS AFFECTING NUTRITIONAL BENEFIT OF AA SOLUTION

Firstly, as there is no single parameter to measure comprehensive nutritional status, parameters used in clinical studies vary widely, and single or a few of those parameters may reflect limited aspects of complex nutritional status. Secondly, the relatively small sample size in most clinical studies may provide poor statistical power. Thirdly, study design may affect the study outcome. Most clinical studies have been observational nature. Some studies were carried out in malnourished patients and the other studies carried out in either stable or nutritionally unselected patients. Fourthly, although dietary intake is the most important factor in determining nutritional status, consistent dietary control and monitoring are difficult especially in long-term studies. In addition, comorbid conditions such as peritonitis, heart failure, and infectious illness during the study period are also hindrances of nutritional studies.

Recently, two different categories of malnutrition were suggested: malnutrition related to inflammation (type II) and malnutrition not related to inflammation (type I).[29] A nutrient supplement, either dietary or peritoneal, is helpful in reverting nutritional status in type I malnutrition whereas it is not sufficient in type II malnutrition patients without correction of the causes of inflammation. The inflammatory status of patients has not been well studied.

Furthermore, protein anabolism after AA supplementation is improved with a sufficient calorie intake. Therefore, to maximize AA utilization for protein anabolism, it is recommended that an AA solution be used during the day with sufficient dietary energy intake. A recent study using AA plus glucose dialysis solution obtained by cycler-assisted mixing of one bag of 2.5 l of AA and four bags of 2.5 l glucose showed improved net protein balance and a positive conversion of nitrogen balance.[14]

All of the above-mentioned factors and conditions can potentially influence the nutritional benefit of an AA solution and may partly explain the differences observed in clinical studies.

OTHER BENEFITS OF AA SOLUTIONS

A non-glucose AA solution has positive effects on fat metabolism. Plasma cholesterol level and triglyceride level decreased during the use of AA solution for 3 months,[30] 6 months,[27] or 3 years.[28] Another 6-month study showed a significant decrease in total body fat mass during the use of an AA solution, whereas it increased during the use of glucose solutions.[31]

A LONG-TERM CLINICAL STUDY INVESTIGATING FACTORS AFFECTING NUTRITIONAL EFFECTS OF AA SOLUTION

As there is no single parameter that can measure comprehensive nutrition status, parameters used in clinical studies vary widely, and single or a few of those parameters may reflect limited aspects of complex nutritional status. Although there are several studies showing some nutritional benefit of AA solutions in PD patients, the long-term efficacy of AA solutions is not yet clear. Moreover, there may be a group of patients who gain more nutritional benefits with AA solutions than others. It would be useful clinically to identify factors that play a critical role in determining the effect of AA solutions on nutritional status. To gain further insight on these factors, we carried out a long-term observational study in 46 malnourished CAPD patients (mean age, 53.2 ± 8.6 years and mean PD duration, 75.1 ± 34.6 months). Malnourished patients were identified as patients meeting two or more of the following: (1) serum albumin concentration < 3.5 g/dl; (2) normalized protein equivalent of total nitrogen appearance < 1.0 g/kg/day; (3) SGA score < 5. A 1.1% AA solution was used once daily for 1 year. To evaluate general nutritional status during the study, biochemical, dialysis, anthropometric, and nutritional parameters including dietary calorie/protein intake were assessed at baseline and every 3 months. Parameters at baseline and at the end of the study were compared. In order to ascertain factors determining the efficacy of the AA solution, patients were classified as either responders or non-responders. Change in lean body mass (LBM) estimated by creatinine kinetics was used as an ultimate nutritional parameter in this study. Depending on the direction of changes in LBM, patients were divided into two groups by applying the regression model to the repeated observations for each patient over a year. Patients with a positive estimated coefficient for LBM in the fitted regression model was classified as responders and patients having neutral or negative estimated coefficient were classified as non-responders.

RESULTS

Mean values of blood urea nitrogen, creatinine, LBM, % LBM, normalized protein equivalent of total nitrogen appearance, serum IGF-1 level, back lift strength, and SGA score increased significantly over 12 months (Table 2). Thirty-one patients were identified as responders and 12 as non-responders. Hand grip strength and back lift strength were significantly higher in responders at baseline. Residual renal function was

Table 2 | Changes of biochemical, nutritional and adequacy parameters in 46 malnourished CAPD patients using AA solutions for 1 year

Parameters	Baseline	3 months	6 months	9 months	12 months
BUN (mg/dl)	49.6±14.1	70.2±11.9†	70.1±15.0†	69.8±15.7†	72.1±14.6†
Cr (mg/dl)	10.2±2.1	10.4±2.6	10.8±2.7†	11.3±2.8†	11.7±2.8†
Protein (g/dl)	6.4±0.6	6.3±0.5	6.2±0.5	6.3±0.6	6.2±0.6
Albumin (g/dl)	3.3±0.3	3.3±0.2	3.2±0.3	3.2±0.3	3.2±0.3
Prealbumin (mg/dl)	50.6±15.6	50.6±15.6	49.6±17.9	47.9±17.3	47.3±14.2
Hemoglobin (g/dl)	8.9±1.4	8.9±2.0	9.3±1.9	9.5±1.2	9.5±1.5
Potassium (meq/l)	4.1±0.5	3.9±0.5	4.0±0.7	4.0±0.6	4.0±0.6
Phosphorus (mg/dl)	4.5±1.1	4.3±1.1	4.3±1.2	4.3±1.1	4.4±1.1
IGF-1 (ng/ml)	191±98	207±93†	200±103	278±120†	286±94†
Total CO_2 (meq/l)	26.4±3.2	24.6±2.3†	25.7±2.5	25.2±3.1	23.8±2.3†
C-reactive protein (mg/dl)	0.49±0.32	0.41±0.41	0.68±1.24	0.32±0.29	0.35±0.38
LBMCr (kg)	40.5±6.9	42.1±8.8†	41.8±8.0†	43.4±8.7†	43.9±8.5†
LBMCr (% BW)	69.6±8.3	71.8±10.3†	72.3±9.3†	73.9±9.8†	74.0±9.7†
nPNA (g/kg/day)	0.9±0.1	1.2±0.1†	1.2±0.1†	1.2±0.1†	1.2±0.1†
SGA	5.1±0.9	5.4 ±0.7†	5.6±0.8†	5.7±0.6†	5.9±0.6†
Hand grip strength (kg)	21.6±6.6	23.4±7.6†	23.4±7.5†	21.6±7.8	21.1±7.2
Back lift strength (kg)	57.6±24.4	64.4±28.0†	67.7±26.1†	63.7±26.7†	63.0±27.1†
Dialysis parameters					
Weekly *Kt/V*	2.1±0.36	2.1±0.37	2.1±0.26	2.1±0.26	2.0±0.36
SCCr (l/wk/1.73m^2)	69.4±11.4	70.5±14.5	68.0±13.0	66.9±12.7	64.5±12.2†
Anthropometry					
LBM-anthro (kg)	44.1±6.8	43.8±6.4	43.7±5.8	44.5±6.4	46.1±6.5
Mid-arm Cx (cm)	25.6±3.4	26.0±3.4	26.1±3.6	26.1±3.7	27.3±3.3
Dietary intake					
Calorie (kcal/kg/day)	28.4±3.1	23.6±3.3	23.4±4.6	24.2±3.7	24.6±4.8
Protein (g/kg/day)	0.8±0.1	0.8±0.1	0.8±0.1	0.8±0.1	0.9±0.2

AA, amino acid; BUN, blood urea nitrogen; CAPD, continuous ambulatory peritoneal dialysis; IGF-1, insulin-like growth factor-1; LBM-anthro, lean body mass calculated by anthropometric measurements; Mid-arm Cx, mid-arm circumference; nPNA, normalized protein nitrogen appearance; SCCr, standardized creatinine clearance; SGA, subjective global assessment; wk, week.
†$P<0.05$ compared with baseline.

Table 3 | Comparison of parameters between responders and non-responders

	Responders (*n*=31)		Non-responders (*n*=12)	
	At baseline	During AA	At baseline	During AA
BUN (mg/dl)	49.2±14.2	72.3±12.6†	50.0±14.3	67.1±12.0†
Cr (mg/dl)	10.6±2.0	11.8±2.6†	9.7±2.1	9.7±2.3
Protein (g/dl)	6.6±0.7	6.3±0.5	6.2±0.5	6.2±0.4
Albumin (g/dl)	3.4±0.2	3.3±0.2	3.2±0.3	3.2±0.2
LBMCr (kg)	41.6±7.7	44.9±8.9†	39.2±5.9	39.1±6.2
% LBMCr	70.8±8.9	76.4±9.1†	68.1±7.6	68.4±7.5
nPNA (g/kg/day)	0.9±0.1	1.2±0.1†	0.9±0.1	1.1±0.1†
TCO_2 (mmol/l)	26.8±3.3	25.0±1.5	25.8±3.0	24.8±1.6
SGA	5.2±0.7	5.8±0.6†	5.0±1.1	5.4±0.7†
Hand grip strength (kg)	23.2±7.3‡	24.3±7.7†	19.7±5.3‡	19.3±6.1
Back lift strength (kg)	67.0±27.4‡	75.3±26.6†	46.4±13.9‡	49.1±12.9
Weekly *Kt/V*	2.0±0.2	2.1±0.2	2.1±0.3	2.1±0.3
SCCr (l/wk/1.73m^2)	66.9±7.4	65.9±9.0	72.3±15.1	70.8±14.3
Dietary calorie intake (kcal/kg/day)	23.8±2.7	23.9±3.0	23.1±3.1	24.6±3.8
Dietary protein intake (g/kg/day)	0.8±0.1	0.8±0.1	0.8±0.1	0.8±0.2
RRF (ml/min)	0.30±0.80	NA	0.03±0.20	NA

AA, amino acid; BUN, blood urea nitrogen; LBM-anthro, lean body mass calculated by anthropometric measurements; NA, not available; nPNA, normalized protein nitrogen appearance;RRF, residual renal function; SCCr, standardized creatinine clearance; SGA, subjective global assessment; wk, week.
RRF calculated as 1/2(creatinine+urea clearances).
†$P<0.05$ for comparison of baseline and after AA; ‡$P<0.05$ for comparison between responders and non-responders at baseline.

negligible in both groups, but more patients had some residual renal function in responders. Other parameters did not differ between the two groups (Table 3). In summary, several nutritional parameters including LBM, back lift strength, and SGA improved following use of the AA solution. Thirty-one of 43 patients (72%) showed nutritional benefit based on the changes of LBM, especially in those with better muscle strength and higher residual renal function at baseline.

CONCLUSION

It can be concluded that long-term use of an AA dialysis solution can induce improvement of nutritional status in a substantial number of PD patients. Use of AA dialysis solution is associated with an increase in serum AA level, improved nitrogen balance, maintenance of serum albumin level, and maintenance, or improvement of LBM. Improvement in nutritional status with AA solution can be expected in mild to moderately malnourished patients who maintain relatively good muscle strength with some residual renal function. In our study, a declining trend in serum albumin level and LBM observed during the pre-AA solution period was stabilized or improved in the responders (data not shown).

Conflicting results of various clinical studies may reflect the complexity of nutritional status that cannot be measured by one or only a few of the known parameters.

There are other benefits of using AA solutions such as improved fat metabolism inducing lesser atherosclerotic burden. The potential benefit of an AA solution as a non-glucose osmotic agent to preserve membrane function and to reduce glucose load in long-term PD patients deserves further evaluation.

REFERENCES

1. Young GA, Kopple JD, Lindholm B *et al.* Nutritional assessment of continuous ambulatory peritoneal dialysis patients: an international study. *Am J Kidney Dis* 1991; **17**: 462–471.
2. Kopple JD. Effect of nutrition on morbidity and mortality in maintenance dialysis patients. *Am J Kidney Dis* 1994; **24**: 1002–1009.
3. McCusker FX, Teehan BP, Thorpe KE *et al.* How much peritoneal dialysis is required for the maintenance of a good nutritional state? Canada-USA (CANUSA) Peritoneal Dialysis Study Group. *Kidney Int* 1996; **56**(Suppl): S56–S61.
4. Kang DH, Kang EW, Choi SR *et al.* Nutritional problems of Asian peritoneal dialysis patients. *Perit Dial Int* 2003; **23**(Suppl 2): S58–S64.
5. Wang T, Heimburger O, Bergstrom J, Lindholm B. Nutritional problems in peritoneal dialysis: an overview. *Perit Dial Int* 1999; **19**: S297–303.
6. Blumenkrantz MJ, Gahl GM, Kopple JD *et al.* Protein losses during peritoneal dialysis. *Kidney Int* 1981; **19**: 593–602.
7. Kopple JD, Bernard D, Messana J *et al.* Treatment of malnourished CAPD patients with an amino acid based dialysate. *Kidney Int* 1995; **47**: 1148–1157.
8. Oren A, Wu G, Anderson GH *et al.* Effective use of amino acid dialysate over four weeks in CAPD patients. *Trans Am Soc Artif Intern Organs* 1983; **29**: 604–610.
9. Young Ga, Dibble JB, Hobson SM *et al.* The use of an amino acid and glucose solutions in CAPD. *Perit Dial Bull* 1985; **5**: 215–218.
10. Bruno M, Bagnis C, Marangella M *et al.* CAPD with an amino acid dialysis solution: a long-term, cross-over study. *Kidney Int* 1989; **35**: 1189–1194.
11. Arfeen S, Goodship TH, Kirkwood A *et al.* 1% amino acid peritoneal dialysate: single-cycle study in diabetic patients with end-stage renal disease. *Am J Kidney Dis* 1994; **23**: 86–90.
12. Jones MR, Hagen T, Boyle CA *et al.* Treatment pf malnutiriotn with 1.1% amino acid peritoneal dialysis solution: results of a multicenter outpatient study. *Am J Kidney Dis* 1998; **32**: 76–769.
13. Jones MR, Gehr TW, Burkart JM *et al.* Replacement of amino acid and protein losses with 1.1% amino acid peritoneal dialysis solutions. *Perit Dial Int* 1998; **18**: 210–216.
14. Tjiong HL, van den Berg JW, Wattimena JL *et al.* Dialysate as food: combined amino acid and glucose dialysate improves protein anabolism in renal failure patients on automated peritoneal dialysis. *J Am Kidney Dis* 2005; **16**: 1486–1493.
15. Park MS, Heimburger O, Bergstrom J *et al.* Peritoenal transport during dialysis with amino acid-based solutions. *Perit Dial Int* 1993; **13**: 280–288.
16. Plum J, Erren C, Fieseler C *et al.* An amino acid-based peritoneal dialysis fluid buffered with bicarbonate versus glucose/bicarbonate and glucose/lactate solutions: an intraindividual randomized study. *Perit Dial Int* 1999; **19**: 418–428.
17. Jones M. Amino acid solutions for CAPD: rationale and clinical experience. *Miner Electrolyte Metab* 1995; **18**: 309–315.
18. National Kidney Foundation K/DOQI clinical practice guidelines for nutrition in chronic renal failure. *Am J Kidney Dis* 2000; **35**(Suppl 2): S17–S31.
19. Han DS, Lee SW, Kang SW *et al.* Factors affecting low values of serum albumin in CAPD patients. *Adv Perit Dial* 1996; **12**: 288–292.
20. Canada-USA (CANUSA) Peritoneal Dialysis Study Group. Adequacy of dialysis and nutrition in continuous peritoneal dialysis: association with clinical outcomes. *J Am Soc Nephrol* 1996; **7**: 198–207.
21. Markku A, Kirsi V, Kjell N *et al.* Amino acid based peritoneal dialysis solution improves amino acid transport into skeletal muscle. *J Am Soc Nephrol* 2002; **13**: 205A.
22. Yang SY, Huang JW, Shih KY *et al.* Factors associated with increased plasma homocysteine in patients using an amino acid peritoneal dialysis fluid. *Nephrol Dial Transplant* 2005; **20**: 161–166.
23. Garibotto G, Sofia A, Canepa A *et al.* Acute effects of peritoneal dialysis with dialysates containing dextrose or dextrose and amino acids on muscle protein turnover. *J Am Soc Nephrol* 2001; **12**: 557–567.
24. Misra M, Ashworth J, Reaveley Da *et al.* Nutritional effects of amino acid dialysate (Nutrineal) in CAPD patients. *Adv Perit Dial* 1996; **12**: 311–314.
25. De Bisschop E, Allein S, Van der Niepen P *et al.* Effect of amino acid administration on uremic muscle metabolism: a 31 P-spectroscopy study. *Kidney Int* 1997; **51**: 1182–1187.
26. Grzegorzewska AE, Mariak I, Dobrowolska-Zachwieja A, Szajdak L. Effects of amino acid dialysis solution on the nutrition of continuous ambulatory peritoneal dialysis patients. *Perit Dial Int* 1999; **19**: 462–470.
27. Misra M, Reaveley D, Ashwaorth J *et al.* Six-month prospective cross-over study to determine the effects of 1.1% amino acid dialysate in lipid metabolism in patients on continuous ambulatory peritoneal dialysis. *Perit Dial Int* 1997; **17**: 279–286.
28. Li FK, Chan LY, Woo JC *et al.* A 3-year, prospective, randomized, controlled study on amino acid dialysis in *patients* on CAPD. *Am J Kidney Dis* 2003; **42**: 173–183.
29. Stenvinkel P, Heimburger O, Lindholm *et al.* Are there two types of malnutrition in chronic renal failure? Evidence for relationships between malnutrition, inflammation and atherosclerosis (MIA syndrome). *Nephrol Dial Transplant* 2000; **15**: 953–960.
30. Bruno M, Bagnis C, Marangell M *et al.* CAPD with an amino acid dialysis solution: a long-term, cross-over study. *Kidney Int* 1989; **35**: 1189–1194.
31. Maurer O, Saxenhofer H, Jaeger P *et al.* Six-month overnight administration of intraperitoneal amino acids not improved lean mass. *Clin Nephrol* 1996; **45**: 303–309.