J Turgut Ozal Med Cent
DOI: 10.5455/jtomc.2017.10.128 2018;25(1):45-50

Orginal Article

Relationship between peritoneal permeability with inflammation and subclinical atherosclerosis in peritoneal dialysis patients

Ozlem Yayar[1], Baris Eser[2], Alper Bozkurt[3]

[1]Canakkale State Hospital, Department of Nephrology, Canakkale, Turkey
[2]Hitit University, Erol Olcok Training and Research Hospital, Department of Nephrology, Corum, Turkey
[3]Private 100th Year Hospital, Department of Radiology, Ankara, Turkey

Abstract

Aim: High permeability in peritoneal dialysis (PD) is reported to be associated with increased mortality. Cardiovascular disease is the most important cause of morbidity and mortality in patients with end-stage renal disease. The inflammation is thought to take part in development of atherosclerosis. The aim of this study is to investigate the relation of peritoneal permeability type with carotid intima media thickness (CIMT) in PD patients.

Material and Methods: Based on the standard peritoneal equilibration test, 56 PD patients (28 male) were divided in two transporter groups: low (low+low average) and high (high+high average) permeability. C-reactive protein (CRP) measured as a marker of inflammation and CIMT was evaluated by high-resolution B-mode ultrasonography.

Results: Twenty one patients were low and 35 of them were high peritoneal transporters. Mean CRP level was significantly higher in the high permeability group (HPG) (1.62±1.7 vs 0.84±1 mg/dL; p=0.006). CIMT was higher in the HPG but this difference did not reach statistical significance (0.810±0.160 vs 0.740±0.160 mm; p=0.16).

Conclusions: CRP, an indicator of inflammation, was found to be higher in the HPG. CIMT also was found to be higher in HPG although it was not statistically significant. One of the causes of increased mortality rate in this group of patients may be explained by inflammation and atherosclerosis.

Keywords: Atherosclerosis; Inflammation; Peritoneal Dialysis; Peritoneal Permeability.

INTRODUCTION

Cardiovascular disease (CVD) is the most common cause of mortality in end-stage renal disease (ESRD) patients, accounting nearly 40% of all-cause mortality (1). Non-traditional risk factors, as well as traditional risk factors such as diabetes, hypertension, smoking, and dyslipidemia, contribute to a high prevalence of CVD and mortality in dialysis patients (2). Chronic inflammation as a non-traditional risk factor is shown to be an important predictor of morbidity and mortality in ESRD patients (3). The causes of chronic inflammation in dialysis patients are multifactorial (4).

Uremia per se (5) decreased residual renal function (RRF) (6,7), periodontal disease (8), and infection of microorganisms such as Chlamydia pneumonia (9) induce the production of pro-inflammatory cytokines such as CRP and interleukin-6 (IL-6). Specifically, in peritoneal dialysis (PD) patients, dialysis catheter implantation, bio-incompatibility of PD solutions, and exposure of endotoxins can induce inflammatory reactions in the peritoneum and might cause increased inflammatory status in PD patients (4,10).

Peritoneal membrane function assessed by the peritoneal equilibration test is associated with clinical outcomes in PD patients and showed high transport status to be associated with poor survival in these patients (11).

As a sign of atherosclerosis increased carotid intima-media thickness (CIMT) is widely used and accepted as a strong predictor of cardiovascular events and mortality in ESRD patients (12). The aim of this study is to determine the relationship of inflammation and subclinical atherosclerosis in high-peritoneal transporters.

Received: 08.10.2017 **Accepted:** 14.12.2017
Corresponding Author: Baris Eser, Hitit University, Erol Olcok Training and Research Hospital, Department of Nephrology, Corum, Turkey, E-mail: beser374@gmail.com

MATERIAL and METHODS

Study Population

This cross-sectional study included 56 PD patients and was approved by the local ethics committee and was conducted in accordance with Declaration of Helsinki. All participants provided written informed consent to participate in the study.

All subjects were clinically stable at the time of evaluation. Exclusion criteria were the presence of infection (acute and chronic), known collagen vascular disease, malignancy history and recent history of a cardiovascular disease diagnosed by angiography or scintigraphy. Patients who had PD catheter insertion in last 30 days were also excluded. Peritoneal dialysis patients followed by nephrology outpatient department were included in the study. For all patients, demographic parameters and co-morbidities at the time of inclusion were recorded from patients' medical files.

Laboratory

To simulate the actual dialysis conditions, all patients had a full abdomen at the time of sampling. Blood samples for laboratory measurements were drawn from the antecubital vein 2 hours after the first PD exchange after overnight fasting. Serum was separated from blood within 30 minutes.

Serum total cholesterol and triglyceride levels were measured by colorimetric analysis (GPO-PAP and CHOD-PAP; Boehringer-Mannheim, Mannheim, Germany). High-density lipoprotein cholesterol was measured by phosphotungstic acid precipitation method. CRP was measured by the immunonephelometric method (IMECE). Other biochemical parameters were measured by computerized auto analyzer (Hitachi 717; Boehringer-Mannheim).

Peritoneal Equilibration Test (PET) and Assessment of Dialysis Adequacy

A modified PET using 4.25% glucose dialysate was performed and the value of the dialysate-to-plasma creatinine ratio at 4 h was calculated as previously reported (18).

The patients were grouped as high (high+high average) and low (low+low average) transporters according to modified PET test. In addition, urea kinetic studies were performed from a 24-hour collection of dialysate and urine at baseline. Kt/V urea was determined from the total loss of urea nitrogen in spent dialysate using PD Adequest 2.0 for Windows software (Baxter Healthcare, Deerfield, Ill., USA). Residual glomerular filtration rate (GFR) was estimated by a 24-hour urine collection.

Measurement of Carotid Intima-Media Thickness

Ultrasonographical B-mode imaging of bilateral carotid arteries was performed with a high-resolution real-time ultrasonography with a 12MHz linear-assay transducer (Mindray DC7, China). Evaluations were performed by a single trained radiologist who was blinded to the clinical status and laboratory parameters of the patients. Common carotid arteries, carotid bulb and internal carotid arteries were examined by two different longitudinal projections. At each longitudinal projection, CIMT was conducted from the site of the greater thickness. CIMT was defined as the distance between the leading edges of the lumen interface at the far wall in plaque-free arterial segments. Three different measurements were taken. The value was expressed as an average of the maximal CIMT.

Statistical analysis

Statistical analysis was performed by using statistical package SPSS version 19.0 (SPSS Inc., IL, USA). All variables were expressed as the mean ± SD unless otherwise indicated. The Kolmogorov-Smirnov test was used to analyze the normality of distribution. Pearson's correlation analysis was used to evaluate the relation between CIMT, CRP and other parameters. Patients were grouped in two according to the transport status. Parameters shown to correlate with CIMT were analyzed by linear regression analysis. A level of $p < 0.05$ was accepted as significant.

RESULTS

Baseline characteristics of the patients are shown in Table 1.

Table 1. Properties of patients

Variable	n=56
Age, years	46.3 ± 13.2
Gender, female; n, (%)	28 (50)
DV, months	67.7 ± 38.6
Past peritonitis, n, (%)	20 (35.7)
Diabetes, n, %	7 (12.5)
Hypertension, n, (%)	34 (60.7)
Smoking, n, (%)	13 (23.2)
MAP, mmHg	98.3 ± 18.7
BMI, kg/m²	25.2 ± 3.8
Kt/V	2.1 ± 0.43
Glucose, mg/dL	104 ± 23
Albumin, g/dL	3.78 ± 0.4
Hemoglobin, g/dL	11.4 ± 1.9
Ferritin, ng/mL	293 ± 388
CRP, g/dL	1.33 ± 1.5
Calcium, mg/dL	9.2 ±0.7
Phosphorus, mg/dL	4.9 ± 1.4
Parathormone, pg/mL	484 ± 326
T.chol, mg/dL	186 ± 45
LDL-chol, mg/dL	111 ± 34
Triglyceride, mg/dL	175 ± 110
CIMT, mm	0.790 ± 0.160

BMI: Body mass index, CRP: C-reactive protein, CIMT; carotid intima-media thickness, DV; Dialysis vintage, LDL-chol; low density lipoprotein cholesterol, MAP: Mean arterial pressure, T.Chol; Total cholesterol

Mean age was 46.3 ± 13.2 years, mean duration of dialysis was 67.7 ± 38.6 months and 50% of the patients were female. The prevalence of diabetes and hypertension was 12.5% and 60.7% respectively.

Based on the modified PET, 56 PD patients were grouped in two: Low (low+low average, n=21) and high (high+high average, n=35) permeability. Comparison of groups can be seen in Table 2.

Table 2. Comparison of low and high peritoneal transport group

Variable	Low transport (n=21)	High transport (n=35)	p
Age, years	42.6 ± 12.1	48.6 ± 13.4	0.12
Gender, female; n, (%)	11 (52.4)	17 (48)	0.78
DV, months	68.2 ± 34.0	70.9 ± 25.6	0.45
Past peritonitis, n, (%)	6 (28.6)	14 (40)	0.39
Diabetes, n (%)	2 (9.5)	5 (14.3)	0.6
Hypertension, n, (%)	11 (52.4)	23 (65.7)	0.32
Smoking, n, (%)	3 (14.3)	10 (28.6)	0.22
MAP, mmHg	97.9 ± 19.2	98.6 ± 18.7	0.63
BMI, kg/m²	24.1 ± 3.5	25.8 ± 3.8	0.11
Kt/V	2.2 ± 0.4	2.0 ± 0.5	0.13
Glucose, mg/dL	105 ± 31.1	103 ± 16	0.25
Albumin, g/dL	3.9 ± 0.4	3.7 ± 0.4	0.33
Hemoglobin, g/dL	11.4 ± 1.8	11.3 ± 2.0	0.78
Ferritin, ng/mL	303 ± 453	287 ± 350	0.33
CRP, g/dL	0.8 ± 1.0	1.62 ± 1.7	0.006
Calcium, mg/dL	9.1 ± 0.6	9.2 ± 0.8	0.67
Phosphorus, mg/dL	5.1 ± 1.5	4.9 ± 1.3	0.65
Parathormone, pg/mL	531 ± 334	456 ± 324	0.38
T.chol, mg/dL	182 ± 50	188 ± 43	0.56
LDL-chol, mg/dL	108 ± 36	111.9 ± 33.4	0.77
Triglyceride, mg/dL	145 ± 95	193 ± 116	0.25
CIMT, mm	0.740 ± 0.160	0.810 ± 0.160	0.16

BMI: Body mass index, CRP: C-reactive protein, CIMT; carotid intima-media thickness, DV; Dialysis vintage, LDL-chol; low density lipoprotein cholesterol, MAP: Mean arterial pressure, T.Chol; Total cholesterol

There were no difference in terms of age (42.6 ± 12.1 vs 48.6 ± 13.4; p = 0.12) and albumin (3.9±0.4 vs 3.7 ± 0.4; p = 0.33) levels. CRP was found to be statistically significantly higher in the high transport group (0.8 ± 1.0 vs 1.62 ± 1.7; p = 0.006). CIMT tends to be higher in high transport group but this was not statistically significant (0.740 ± 0.160 vs 0.810 ± 0.160; p = 0.16).

Patients were grouped in two according to types of PD solutions (conventional and biocompatible solutions, Table 3). Thirty-one of the patients were using conventional PD solutions while 25 of them were using biocompatible PD solutions. The only difference between two groups was the PD vintage (84.2 ± 35.1 months in the conventional group and 47.3 ± 33 months in biocompatible solution group p < 0.05). CRP and transport rate was not different between groups.

Patients were grouped in two according to the presence of renal residual function (RRF) (Table 4). Nineteen (33.9%) of the patients had RRF and the only statistically significant difference between two groups was dialysis vintage (83 ± 33.3 in RRF (-) vs 38.1 ± 30.4 in RRF (+); p < 0.001).

Correlation analysis of CRP and CIMT was made in high transport group. In the high transport group CRP was found to be positively correlated with dialysis vintage (r = 0.268; p = 0.046), CIMT (r = 0.284; p = 0.034) and negatively correlated with ultrafiltration volume (r= -0.300; p = 0.025). In the high transport group CIMT was found to be positively correlated with age (r=0.49; p < 0.001) and CRP (r = 0.284; p = 0.034), (Figure 1). In low transport group CRP was correlated with dialysis vintage (r = 0.272; p = 0.047). In low transport group CIMT was positively correlated with age (r = 0.42; p = 0.01).

In a linear regression analysis in the high transport group, the model including CRP and age were found to be statistically significant (F = 11.39; p < 0.001). When the parameters are analyzed age factor (β = 0.471; P < 0.001) and CRP (β = 0.247; p = 0.037) were found to be independent determinants of CIMT. R^2 value explaining the overall biological variability in CIMT explained by age and CRP was found to be 0.301.

Table 3. Comparison of patients according to peritoneal dialysis solutions

Variable	Conventional (n=31)	Biocompatible (n=25)	p
Age , years	47 ± 13.6	45.5 ± 12.8	0.627
Gender, female; n, (%)	14 (45.2)	14 (56)	0.42
DV, months	84.2 ± 35.1	47.3 ± 33.0	< 0.001
Past peritonitis, n, (%)	9 (29)	11 (44)	0.245
Diabetes, n, (%)	4 (12.9)	3 (12)	0.919
Hypertension, n, (%)	19 (61.3)	15 (60)	0.922
Smoking, n, (%)	6 (19.4)	7 (28)	0.446
HPTR, n, (%)	21 (67)	14 (56)	0.367
MAP, mmHg	95.2 ± 12.3	102.1 ± 24.2	0.206
BMI, kg/m²	24.3 ± 3.9	26.2 ± 3.4	0.075
Kt/V	2.1 ± 0.4	2.1 ± 0.5	0.830
Glucose, mg/dL	105 ± 22	102 ± 24	0.225
Albumin, g/dL	3.8 ± 0.4	3.8 ± 0.4	0.656
Hemoglobin, g/dL	11.6 ± 2.0	11 ± 1.8	0.410
C-reactive protein, g/dL	1.3 ± 1.2	1.4 ± 1.9	0.662
Calcium, mg/dL	9.3 ± 0.7	9.1 ± 0.7	0.400
Phosphorus, mg/dL	4.8 ± 1.4	5.2 ± 1.2	0.287
Parathormone, pg/mL	485 ± 353	484 ± 297	0.742
LDL-chol, mg/dL	110 ± 39	111 ± 28	0.792
Triglyceride, mg/dL	196 ± 124	148 ± 84	0.174
CIMT, mm	0.770 ± 0.160	0.810 ± 0.170	0.666

BMI: Body mass index, CIMT; Carotid intima-media thickness, DV; Dialysis vintage, HPTR: High Peritoneal Transport Rate, LDL-chol; low density lipoprotein cholesterol, MAP: Mean arterial pressure

Table 4. Comparison of patients according to renal residual function (RRF)

Variable	RRF (-) (n=37)	RRF (+) (n=19)	p
Age, years	44.9 ± 12.4	49.2 ± 14.5	0.24
Gender, female; n, (%)	20 (54.1)	8 (42.1)	0.40
DV, months	83 ± 33.3	38.1 ± 30.4	< 0.001
Past peritonitis, n, (%)	11 (29.7)	9 (47.9)	0.19
Diabetes, n, (%)	3 (8.1)	4 (21.1)	0.17
Hypertension, n, (%)	21 (56.8)	13 (68.4)	0.40
HPTR, n, (%)	23 (62.2)	12 (63.2)	0.94
MAP, mmHg	95.8 ± 18.5	103.2 ± 18.6	0.08
BMI, kg/m²	25.0 ± 3.7	25.5 ± 4.0	0.79
Kt/V	2.1 ± 0.4	2.06 ± 0.5	0.56
Glucose, mg/dL	101 ± 21	108 ± 26	0.29
Albumin, g/dL	3.8 ± 0.4	3.7 ± 0.4	0.09
Hemoglobin, g/dL	11.4 ± 2.2	11.3 ± 1.4	0.99
CRP, g/dL	1.22 ± 1.1	1.6 ± 2.1	0.93
Calcium, mg/dL	9.3 ± 0.7	9.0 ± 0.6	0.14
Phosphorus, mg/dL	5.0 ± 1.4	4.9 ± 1.3	0.76
Parathormone, pg/mL	531 ± 351	394 ± 258	0.18
LDL-chol, mg/dL	111 ± 35	110 ± 33.1	0.99
Triglyceride, mg/dL	199 ± 124	128 ± 53	0.07
CIMT, mm	0.780 ± 0.140	0.790 ± 0.210	0.87

BMI: Body mass index, CRP. C-reactive protein, CIMT; Carotid intima-media thickness, DV; Dialysis vintage, HPTR: High Peritoneal Transport Rate, LDL-chol; Low density lipoprotein cholesterol, MAP. Mean arterial pressure

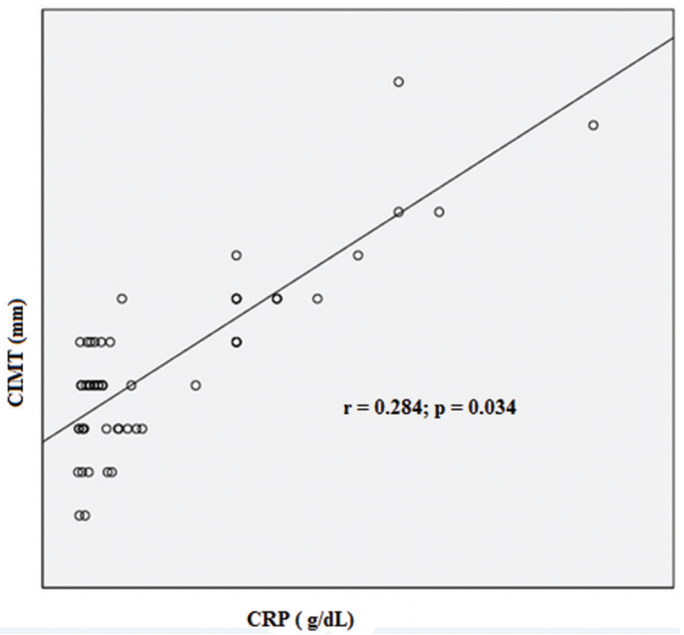

Figure 1. Distribution graph of relationship between carotid intima-media thickness and c-reactive protein

DISCUSSION

There are two main findings of this study: first CRP level is found to be higher in high transporters in respect to low transporters, second CRP and age are found to be independent determinants of CIMT in high transport group.

Chronic inflammation is implicated in increased cardiovascular risk, and CVD is the most common cause of death in ESRD patients (13, 14). CRP has emerged as a useful biomarker for vascular inflammation associated with atherosclerosis. Determination of CRP levels is currently recommended by the American Heart Association in all patients at a risk of CVD (15). Also, the decrease in RRF is connected to a stronger inflammatory response in peritoneal dialysis patients with higher concentrations of CRP (16-18). In our study, CRP was not different between the patients having RRF or not.

Increased CIMT, one of the first signs of early atherosclerosis, is related to high blood pressure, dyslipidemia, hyper-homocysteinemia and micro-inflammation (19, 20). Elevated serum concentrations of CRP is another marker used to stratify CV risk by reflecting chronic inflammation in adult and pediatric CKD and dialysis patients (9, 21-23). Both CIMT and CRP are found to be elevated in pediatric and adult dialysis patients in recent studies (24-27). In our study, although CIMT was not different between groups, correlation analysis yielded CRP and age to be independent determinants of CIMT in high transport group.

Peritoneal membrane function assessed by the peritoneal equilibration test is associated with clinical outcomes in PD patients (11). Previous reports showed high transport status to be associated with poor survival in PD patients (11, 28). Moreover, malnutrition and chronic inflammation are prevalent in high transporters (29-32). Low serum albumin level correlates with malnutrition (28) and is strongly predictive of PD patient mortality (29, 30). The greater prevalence of hypo-albuminemia in high transporters may also arise from hemo-dilution secondary to suboptimal ultrafiltration (31) or from excessive peritoneal protein losses (32). Alternatively, hypoalbuminemia in high transporters may reflect a greater incidence of underlying chronic inflammation (7, 33), although other studies have not observed a significant correlation between dialysate/plasma creatinine 4 h and various inflammatory markers, such as CRP (34). In this study, CRP was found to be positively correlated with dialysis vintage in high transporters. Uremia, peritoneal glucose exposure, and peritonitis can cause local inflammation, in turn, increasing systemic inflammation. As the time on dialysis increases, augmentation of inflammation may be suspected.

Conventional PD solutions are accused of the change in membrane function and inflammation. The potential mechanisms whereby conventional dialysate might drive membrane injury are many and include non-physiological pH (acidic, typically 5.2), lactate buffer,

increased osmolality, high glucose concentrations, and high glucose degradation product (GDP) concentrations. The evidence that low GDP solutions are associated with preservation of mesothelium cells is reasonably compelling from biomarker studies, in particular the increase in dialysate CA-125 levels associated with the use of all the tested biocompatible solutions so far (35) and in one case evidence for reduced epithelial to mesenchymal transition in their morphologic appearance (36). However in our study when patients are compared in terms of biocompatibility of solutions high transporter number was high in conventional solution group but this difference was not statistically different.

In our study, CRP levels were not different between two PD solution groups. Pajek et al. (37) compared the short-term effects of a low GDP peritoneal dialysis solution and a conventional PDS in the intraperitoneal and systemic inflammation. According to the authors, despite the significant reduction of intraperitoneal IL-6 concentration in patients using the bicarbonate and lactate solution, the serum levels of inflammatory markers did not differ between the two solutions. Additionally, the authors did not observe significant difference in the degree of systemic inflammation between both treatments. However, one has to consider that the absence of inflammation signs in both groups in our study may be caused by the nature of the study. This was a cross-sectional study and some of the patients using biocompatible solutions now used conventional solutions before.

There are some limitations of this study. Firstly, this is a cross-sectional study focusing on the relation of peritoneal transport rate with atherosclerosis detected by CIMT. Secondly, the sample size is relatively small. Thirdly, this is not a prospective controlled study so we cannot draw cause-and-effect relationship from our findings. Finally, CIMT measurement is a relatively subjective measurement; computerized programs are used to reduce the error incidence, but we could not use it. Also, we could not use hs-CRP because of financial issues.

In conclusion, inflammation and sub-clinical atherosclerosis is increased in high peritoneal transport group. Mortality increased in this group may be associated with increased inflammation and atherosclerosis.

Acknowledgment

This study has not been financed by any person or institution and the authors declare that they have no conflict of interest.

REFERENCES

1. Johnston N, Dargie H, Jardine A. Diagnosis and treatment of coronary artery disease in patients with chronic kidney disease: Heart 2008;94(8):1080-8.
2. Zoccali C. Traditional and emerging cardiovascular and renal risk factors: an epidemiologic perspective. Kidney Int 2006;70(1):26-33.
3. Pecoits-Filho R, Lindholm B, Stenvinkel P. The malnutrition, inflammation, and atherosclerosis (MIA) syndrome–the heart of the matter. Nephrol Dial Transplant 2002;17(suppl 11):28-31.
4. Wang AY. Consequences of chronic inflammation in peritoneal dialysis. Semin Nephrol 2011;31(2):159-71.
5. Cohen G, Raupachova J, Hörl WH. The uraemic toxin phenylacetic acid contributes to inflammation by priming polymorphonuclear leucocytes. Nephrol Dial Transplant 2013;28(2):421-9.
6. Wang AY, Lam CW, Wang M, Woo J, Chan IH, Lui SF, et al. Circulating soluble vascular cell adhesion molecule 1: relationships with residual renal function, cardiac hypertrophy, and outcome of peritoneal dialysis patients. Am J Kidney Dis 2005;45(4):715-29.
7. Chung SH, Heimburger O, Stenvinkel P, Qureshi AR, Lindholm B. Association between residual renal function, inflammation and patient survival in new peritoneal dialysis patients. Nephrol Dial Transplant 2003;18(3):590-7.
8. Craig RG, Kotanko P, Kamer AR, Levin NW. Periodontal diseases – a modifiable source of systemic inflammation for the end-stage renal disease patient on haemodialysis therapy? Nephrol Dial Transplant 2007;22(2):312-5.
9. Stenvinkel P, Heimburger O, Jogestrand T. Elevated interleukin-6 predicts progressive carotid artery atherosclerosis in dialysis patients: association with chlamydia pneumonia seropositivity. Am J Kidney Dis 2002;39:274-82.
10. Welten AG, Schalkwijk CG, ter Wee PM, Meijer S, van den Born J, Beelen RJ. Single exposure of mesothelial cells to glucose degradation products (GDPs) yields early advanced glycation end-products (AGEs) and a proinflammatory response. Perit Dial Int 2003;23(3):213-21.
11. Rumpsfeld M, McDonald SP, Johnson DW. Higher peritoneal transport status is associated with higher mortality and technique failure in the Australian and New Zealand peritoneal dialysis patient populations. J Am Soc Nephrol 2006;17(1):271-8.
12. Horne BD, Anderson JL, John JM, Weaver A, Bair TL, Jensen KR, et al. Which white blood cell subtypes predict increased cardiovascular risk? J Am Coll Cardiol 2005;45(10):1638-43.
13. Oh KH, Moon JY, Oh J, Kim SG, Hwang YH, Kim S, et al. Baseline peritoneal solute transport rate is not associated with markers of systemic inflammation or comorbidity in incident Korean peritoneal dialysis patients. Nephrol Dial Transplant 2008;23(7):2356-64.
14. Devuyst O, Yool AJ. Aquaporin-1: new developments and perspectives for peritoneal dialysis. Perit Dial Int 2010;30(2):135-41.
15. Pearson TA, Mensah GA, Alexander RW, Anderson JL, Cannon RO 3rd, Criqui M, et al. Markers of inflammation and CV disease: application to clinical and public health practice: a statement for healthcare professionals from the Centers for Disease Control and Prevention and the American Heart Association. Circulation 2003;107(3):499-511.
16. Wang AY. The John F. Maher Award Recipient Lecture 2006. The "heart of peritoneal dialysis": residual renal function. Perit Dial Int 2007;27(2):116-24.
17. Pecoits-Filho R, Stenvinkel P, Wang AY, Heimburger O, Lindholm B. Chronic inflammation in peritoneal dialysis: The search for the holy grail? Perit Dial Int 2004;24(4):327-39.
18. Wang AY, Woo J, Lam CW, Wang M, Sea MM, Lui SF, et al. Is a single time point C-reactive protein predictive of outcome in peritoneal dialysis patients? J Am Soc Nephrol 2003;14(7):1871-9.
19. Litwin M, Trelewicz J, Wawer Z, Antoniewicz J, Wierzbicka A, Rajszys P, et al. Intima–media thickness and arterial elasticity in hypertensive children: controlled study. Pediatr Nephrol 2004;19(7):767-74.

20. Oh J, Wunsch R, Turzer M, Bahner M, Raggi P, Querfeld U, et al. Advanced coronary and carotid arteriopathy in young adults with childhood-onset chronic renal failure. Circulation 2002;106(1):100-5.
21. Nascimento MM, Pecoits-Filho R, Qureshi AR, Hayashi SY, Manfro RC, Pachaly MA, et al. The prognostic impact of fluctuating levels of C-reactive protein in Brazilian haemodialysis patients: a prospective study. Nephrol Dial Transplant 2004;19(11):2803-9.
22. Sylvestre LC, Fonseca KPD, Stinghen AEM, Pereira AM, Meneses RP, Pecoits-Filho R, et al. The malnutrition and inflammation axis in pediatric patients with chronic kidney disease. Pediatr Nephrol 2007;22(6):864-73.
23. Bakkaloglu SA, Buyan N, Funahashi T, Pasaoglu H, Elhan AH, Hasanoglu E, et al. Adiponectin levels and atherosclerotic risk factors in pediatric chronic peritoneal dialysis patients. Perit Dial Int 2005;25(4):357-61.
24. Civilibal M, Caliskan S, Oflaz H, Sever L, Candan C, Canpolat N, et al. Traditional and 'new' CV risk markers and factors in pediatric dialysis patients. Pediatr Nephrol 2007;22:1021-9.
25. Turkmen K, Tonbul HZ, Toker A, Gaipov A, Erdur FM, Cicekler H, et al. The relationship between oxidative stress, inflammation, and atherosclerosis in renal transplant and end-stage renal disease patients. Ren Fail 2012;34(10):1229-37.
26. Kim JK, Park S, Lee MJ, Song YR, Han SH, Kim SG, et al. Plasma levels of soluble receptor for advanced glycation end products (sRAGE) and proinflammatory ligand for RAGE (EN-RAGE) are associated with carotid atherosclerosis in patients with peritoneal dialysis. Atherosclerosis 2012;220(1):208-14.
27. Mutluay R, Konca C, Erten Y, Pasaoglu H, Deger SM, Agirgun C, et al. Predictive markers of asymptomatic atherosclerosis in end-stage renal disease patients. Ren Fail 2010;32(4): 448-54.
28. Han DS, Lee SW, Kang SW, Choi KH, Lee HY, Cho EY, et al. Factors affecting low values of serum albumin in CAPD patients. Adv Perit Dial 1996;12:288-92.
29. Fung L, Pollock CA, Caterson RJ, Mahony JF, Waugh DA, Macadam C, et al. Dialysis adequacy and nutrition determine prognosis in continuous ambulatory peritoneal dialysis patients. J Am Soc Nephrol 1996;7(5):737-44.
30. Struijk DG, Krediet RT, Koomen GC, Boeschoten EW, Hoek FJ, Arisz L. A prospective study of peritoneal transport in CAPD patients. Kidney Int 1994;45(6):1739-44.
31. Harty JC, Boulton H, Venning MC, Gokal R. Is peritoneal permeability an adverse risk factor for malnutrition in CAPD patients? Miner Electrolyte Metab 1996;22(1-2):97-101.
32. Kagan A, Bar Khayim Y. Role of peritoneal loss of albumin in the hypoalbuminemia of continuous ambulatory peritoneal dialysis patients: Relationship to peritoneal transport of solutes. Nephron 1995;71(3):314-20.
33. Breborowicz A, Oreopoulos DG. Evidence for the presence of chronic inflammation during peritoneal dialysis: Therapeutic implications. Perit Dial Int 1997;17 suppl 2:S37-41.
34. Wang T, Heimburger O, Cheng HH, Bergstrom J, Lindholm B. Does a high peritoneal transport rate reflect a state of chronic inflammation? Perit Dial Int 1999;19(1):17-22.
35. Rippe B, Simonsen O, Heimburger O, Christensson A, Haraldsson B, Stelin G, et al. Long-term clinical effects of a peritoneal dialysis fluid with less glucose degradation products. Kidney Int 2001;59(1):348-57.
36. Bajo MA, Perez-Lozano ML, Albar-Vizcaino P, Del Peso G, Castro MJ, Gonzalez-Mateo G, et al. Low-GDP peritoneal dialysis fluid ('balance') has less impact in vitro and ex vivo on epithelial-to-mesenchymal transition (EMT) of mesothelial cells than a standard fluid. Nephrol Dial Transplant 2011;26(1):282-91.
37. Pajek J, Kveder R, Bren A, Gucek A, Ihan A, Osredkar J, et al. Short-term effects of a new bicarbonate/lactate-buffered and conventional peritoneal dialysis fluid on peritoneal and systemic inflammation in CAPD patients: a randomized controlled study. Perit Dial Int 2008;28(1):44-52.