Peritoneal Transport Characteristics at the Beginning and in Long Term Peritoneal Dialysis: a Single Center Experience

Snezana Uncanin¹,², Nafija Serdarevic²,³, Nermina Klapuh²,³, Edhem Haskovic⁴,

ABSTRACT

Introduction: Peritoneal dialysis (PD) is an established treatment for patients with end-stage kidney disease. The method was developed as an alternative to hemodialysis (HD) presenting a patient survival rate equivalent to HD and better preservation of residual renal function. Peritoneal dialysis (PD) patients have different peritoneal membrane permeability (transport) characteristics. High peritoneal membrane permeability is associated with increased mortality risk in the patient population. Aim: The aim of this study was to analyze the importance of the peritoneal membrane transport status in patients treated with continuous ambulatory peritoneal dialysis (CAPD). Methods: The study included 60 adult continuous ambulatory peritoneal dialysis (CAPD) patients, 29 male and 31 female, mean age 56.63±15.06 years. All patients treated with conventional glucose-based PD fluids. For the short term (within 3 month after start of PD) and long term (more than 12 months) peritoneal dialysis analysis of peritoneal transport characteristics has been used peritoneal functional test (PFT). With the test, categorisation of patients was possible into high (H), high-average (HA), low average (LA), and low (L) transporters. Results: Dialysate–to plasma ratio (D/P) of creatinine showed significantly increased over time (0.654±0.141 vs... 0.705±0.13, p<0.001). In multivariate analysis age, gender, time on dialysis, comorbid diseases, diabetes mellitus (DM), serum albumin, were considered as independent factors influencing the PFT. The high transporter group had higher D/P creat (H 0.84±0.03 vs... LA 0.57±0.05, p<0.001), higher proportion of man (H 100% vs... LA 39.5%, p<0.05), higher proportion of patients with comorbid diseases (H 60% vs... LA 20.9%, p<0.05), lower serum albumin concentration (H 29±6.0 vs... LA 37±5.2, p<0.001), lower D4/D0 glucose ( H 0.23±0.07 vs... LA 0.42±0.14, p<0.001), and lower drained volume (H 600±173 vs... LA 1016±355, p<0.001). Conclusion: The PFT was an easy, inexpensive, reliable test to assess peritoneal transport type and it also provided information about peritoneal clearance of solutes and ultrafiltration. Peritoneal transport type classification was recognized not only as aid for prescription, but also as a prognostic index. Keywords: peritoneal solute clearance, equilibration test.

1. INTRODUCTION

Peritoneal dialysis (PD) is an established treatment for patients with end-stage kidney disease. The method was developed as an alternative to hemodialysis (HD) presenting a patient survival rate equivalent to HD and better preservation of residual renal function. In PD, the lining of the peritoneal cavity is used to clear the blood of waste products (1, 2). There are two types of PD: Continuous ambulatory peritoneal dialysis (CAPD) in which the patient performs manual exchange of fluid four or five times per day, and automated peritoneal dialysis (APD) in which the exchange is done by the PD machine at night. CAPD is the usual mode of treatment chosen for patients at the beginning of PD (1, 2). During long term continuous ambulatory peritoneal dialysis (CAPD) treatment, the peritoneal membrane under-
Peritoneal Transport Characteristics at the Beginning and in Long Term Peritoneal Dialysis

goes functional and structural alterations, which may be the consequence of many factors such as peritonitis and continuous exposure to dialysis solutions with high concentrations of glucose and glucose degradation products, low pH and high osmolality. The peritoneal membrane may develops many structural abnormalities, including loss of the mesothelial cell (MC), an increased number of fibroblasts, submesothelial fibrosis and augmented vessel number (1, 2). The most common functional alteration during long term CAPD is increased peritoneal small solute transport rate (PSTR) resulting in impaired ultra filtrations and decreased dialysis efficiency (3, 4). Fluid management is a fundamental function of dialysis therapy. However, evidence suggests that hydration in PD is frequently not normalized. Symptomatic fluid retention is common in PD patients. Fluid overload is an important cause of hypertension in dialysis patients and studies show frequent occult fluid overload, hypertension, and cardiac dysfunction in PD which may deteriorate with time (5–9). For the adequate prescription of peritoneal dialysis, peritoneal transport characteristics should be known (10). Peritoneal solute transport rate (PSTR) is measured by dialysate-to-plasma (D/P) ratios of low molecular weight solutes. The most widely used test for classifying a patient’s peritoneal type has been the peritoneal equilibration test (PET). Peritoneal equilibration test (PET) developed by Twardowski characterizes the transport nature of the patient’s peritoneal membrane (10). Peritoneal equilibration test (PET) is an important tool for managing peritoneal dialysis (PD) prescription. Intra-individual changes can be detected and adjustments can be made. Also, the results of interventions can be examined and complications can be detected at an early stage. The International Society for Peritoneal Dialysis (ISPD) guidelines suggest that the first PET be performed 4–8 weeks after PD commencement (11). High peritoneal permeability has been regarded as a risk factor predicting both technical failure and high mortality rate (12-14). In this study, we compared PET in the beginning of the peritoneal dialysis (within 3 month post-PD initiation) and in long term peritoneal dialysis patients (more than 12 months) to evaluate the changes in the peritoneal membrane character with time in patients treated with continuous ambulatory peritoneal dialysis (CAPD) and factors influencing the peritoneal transport rate.

2. AIM

The aim of this study was to analyze the importance of the peritoneal membrane transport status in patients treated with continuous ambulatory peritoneal dialysis (CAPD).

3. PATIENTS AND METHODS

In prospective a cohort study were included 60 adult continuous ambulatory peritoneal dialysis (CAPD) patients, divided in two groups according to duration of active treatment, first group (within 3 month after start of PD) and second group in long term peritoneal dialysis patients (more than 12 months). For the short term and long term peritoneal dialysis analysis of peritoneal transport characteristics has been used peritoneal functional test (PFT) (Fresenius Medical Care, Bad Homburg, Germany). This computer program is used to give data on renal function, total dialysis weekly clearance urea (Kpt/V) total dialysis weekly creatinine clearance (CcprT), water balance and transport parameters, as well as on nutritional state. The total Kpt/V urea includes two measurements: The peritoneal clearance urea Kpt/V and the renal clearance urea Krt/V. The peritoneal Kpt/V measures the clearance that occurs through the peritoneal membrane. The renal Krt/V measures the clearance performed by the kidney. Also, total dialysis weekly creatinine clearance (CcprT) is the sum of peritoneal (CcprT) and renal (CcrT) creatinine clearance. During the PFT all patients were on CAPD and used standard four two-liter exchanges glucose-containing dialysis solution per day at standardized intervals. The glucose concentrations varied according to the standard program of the individual patients. For the evaluation of peritoneal small solute transport rate (PSTR) we used the dialysate to plasma concentration ratio of creatinine (D/P creat). The patients were divided according to the PET classification into high (D/P creat > 0.81), high-average (D/P creat 0.65 - 0.80), low-average (D/P creat 0.51-0.64) and low (D/P creat ≤0.5) transporters. The mean D/P creatinine ratio at 4 hours was 0.65. Patients with D/P creatinine values lower than 0.5 showed low transport characteristics and high 4–hour dialysate glucose level, which was greater than 52.5 mmol/L. In patients with high solute transport D/P creatinine ratio has been 0.81-1.03 and the 4–hour dialysate glucose level was less than 28.0 mmol/L. The ultrafiltration capacity can be defined as the net fluid removed during a standardized exchange, after 4 hours using 4.25% glucose solution. The diagnosis membrane failure can be made when the net ultra filtered volume is < 400ml after a standardized 4h dwell using a 4.25% glucose solution (ISPQ Guidelines) (11). Glucose, urea, and creatinine, C reactive protein (CRP) were measured in each sample, using conventional techniques in a centralized reference laboratory. No restriction criteria were applied for age, gender, comorbid diseases, serum albumin. Exclusion criteria were the presence of active inflammatory disease, disseminated neoplasia, patients on immunosuppressive therapy and those having a peritonitis episode within the previous 30 days. The clinical characteristics were retrieved from patients files.

Statistical analysis were performed using the Statistical Software Med Calc for the Windows (version 12.6.1.0; Med Calc Software, Mariakerke, Belgium). Continuous variables with normal distribution were presented as mean±standard deviation. Statistical analysis for variables with normal distribution was performed using Student’s t-test or Wilcoxon signed ranked test were used to compare differences between two groups. The median value was used when normal distribution was absent. The Mann-Whitney U test was used to compare variables without normal distribution between two groups. A difference was considered significant when the p value was less than 0.05.

4. RESULTS

Table 1 showed the patient demographics and clinical parameters as taken at entry into the clinical study. A total of 60 patients were included in the study. The mean age was 56.63 years (SD of±15.06) and there were twenty-nine
males (48%) and 31 females (52%). Median period of continuous peritoneal dialysis was 23.05±22.32 months, range 2–96 months. Diabetic nephropathy was the cause of end stage renal disease in 51.7% patients. Other causes of their chronic uremia included nephrosclerosis 9 (15%), chronic glomerulonephritis 2 (3.3%), obstructive nephropathy 1 (1.7%), polycystic kidney disease 3 (5%) and other 14 (23.5%) cases. The high rate of comorbid diseases in these patients is an independent risk factor for mortality, especially cardiovascular and respiratory diseases are. The major causes of comorbidities were cardiovascular diseases defined as previous history of congestive heart failure, myocardial infarction, angina, peripheral vascular disease, or cerebrovascular disease. They were presented, but it was not significant intergroup differences. No statistically significant differences were noted in any of the measured parameters except according to duration of active treatment (2.43±0.18 months vs.. 40.67±19.04, p<0.0001) and number of peritonitis (0.13±0.45 vs.. 0.9±1.09, p<0.0004) between two groups in terms of other demographic and clinical parameters.

The biochemical parameters of this study are shown in Table 2. Between the two groups, significant change was observed between cholesterol (4.709±1.388 vs. 5.312±1.407, p=0.0442), LDLc (2.469±1.063, vs.. 3.300±1.560, p=0.0266) and CRP (2.7 vs.. 5.45, p=0.0412). Serum albumin concentration was significantly lower into a short-term group, compared to a long-term PD group (33.367±3.184 vs.. 37.033±4.327, p<0.0002 ).

The measurements of peritoneal solute transport rate (PSTR) of small solute, dialysis adequacy and nutritional status are shown in Table 3. Significant differences in membrane characteristics evolved using plasma dialysate (D/P) creatinine were found in patients on peritoneal dialysis less than 3 months compared to patients treated with long-term CAPD. Dialysate-to plasma ratio (D/P) of creatinine in the first group was 0.65±0.141 and in the second group 0.705±0.13, showed significantly increased over time (p<0.001). In the second group, the dialysis adequacy parameter was significantly reduced (total weekly Kt/V urea and total weekly creatinine clearance).

In both groups, normalize catabolic rate (nPCR) did not show any significant differences compared with each other. Transport status was categorized as low, low average, high average and high as per the standard definition. As can be seen from Table 4, the PET demonstrated that there were 2 high transporter patients (6.6%), 5 high average transporters (16.7%), 25 low average transporters (76.7%) in the first group (within 3 month post-PD initiation). In the second group, there were more patients with high transporters 5 (10%) and high average transporters 7 (23.3%), and less low average transporters 20 (66.7%). In both groups there were no patients in low category. Low average transporters were most numerous in both study groups. The clinical characteristics of the four transport groups are described in Table 5. There was a significant difference

| Sex (male vs.female) (n) | CAPD < 3 months (n=30) | CAPD > 12 months (n=30) | P |
|--------------------------|------------------------|------------------------|---|
| Age (years) | 53.63±14.44 | 59.63±15.32 | 0.1239 |
| PD duration (months) | 2.43±0.18 | 40.67±19.04 | <0.0001 |
| Body mass index (kg/m²) | 24.50±3.46 | 25.91±4.01 | 0.1516 |

| Primary renal disease | CAPD <3 months | CAPD > 12 months | p |
|-----------------------|---------------|------------------|---|
| Diabetic nephropathy | 17 | 14 | 0.6054 |
| Nephrosclerosis | 4 | 5 | 1.0000 |
| Glomerulonephritis | 0 | 2 | 0.4915 |
| Obstructive nephropathy | 0 | 1 | 1.0000 |
| Polycystic kidney disease | 1 | 2 | 1.0000 |
| Other | 8 | 6 | 0.1804 |

| Comorbid disease | CAPD < 3 months (n=30) | CAPD > 12 months (n=30) | P |
|-----------------|------------------------|------------------------|---|
| Myocardial infarction | 1/29 | 2/28 | 1.0000 |
| Angina pectoris | 0/30 | 1/29 | 1.0000 |
| CMP | 1/29 | 3/27 | 0.6120 |
| HTA | 21/9 | 26/4 | 0.2100 |
| Cerebrovascular disease | 0/30 | 1/29 | 1.0000 |
| PVD | 0/30 | 1/29 | 1.0000 |
| Peritonitis | 0.13±0.43 | 0.9±1.09 | 0.0004 |

| Cholesterol (mmol /L) | CAPD < 3 months (X±SD) | CAPD > 12 months (X±SD) | P |
|----------------------|------------------------|------------------------|---|
| 4.709±1.388 | 5.312±1.407 | 0.0442 |
| Triglicerides (mmol /L) | 2.166±1.127 | 2.224±1.332 | 0.7710 |
| LDLc (mmol /L) | 2.469±1.063 | 3.300±1.560 | 0.0266 |
| HDLc (mmol /L) | 4.555±1.671 | 4.839±1.662 | 0.8815 |
| Serum albumin (mmol /L) | 33.367±3.184 | 37.033±4.327 | 0.0002 |

| CRP (mg/l) | CAPD < 3 months (Md, IR) | CAPD > 12 months (Md, IR) | P |
|------------|------------------------|------------------------|---|
| 2.7 (1.5-4.7) | 5.45 (1.75-7.1) | 0.0412 |
and lower drained volumes. We found that high peritoneal transport rate was related to comorbid diseases. It is generally accepted that peritoneal transport rate depends on both effective peritoneal surface area and permeability and that peritoneal permeability is affected by peritoneal blood circulation (19, 20). Many of the mediators produced in the inflammatory process can affect microvascular permeability and vascular tone (21). Thus, our finding of a significant relation between peritoneal transport rate and comorbid diseases suggests that comorbid diseases may affect microcirculation, and may also affect peritoneal transport characteristics in CAPD patients (22). The CANUSA study showed that a greater proportion of patients had diabetes mellitus with higher peritoneal membrane transport rate, according to PET at 1 month after initiation of dialysis (23). Reyes et al. reported that initial D/Pcreat was significantly higher in patients with cardiovascular disease (CVD) (24). In the present study, high transporters had more comorbidities compared to the other groups. The significantly higher proportion of men in the high transporter group is also consistent with previous studies (25, 26). In a study of 60 CAPD patients, Devuyst et al. reported that D/Pcreat was strongly correlated with male gender (27). The CANUSA study showed a significantly increased proportion of man with increased transport rate (25). The cause of this effect is not clear. However, our finding of signifi-

between the groups regarding prevalence of male gender (p<0.05), and comorbid diseases (p<0.05). Serum albumin levels were significantly lower in the H/HA group (p<0.001 vs... LA). There were significant differences in gender, comorbid diseases, serum albumin, ratio of dialysate glucose concentration at 4 hours and at 0 dwell time; Values are express as absolute frequencies and percentages;

5. DISCUSSION

The most serious problem in long term treatment with peritoneal dialysis is worsening of functional and morphological states of peritoneal membrane with increased permeability or decreasing ultrafiltration as well as efficacy of dialysis. In our study significant changes in dialysis-related parameters were found. The peritoneal solute transport, which was evaluated using the di... Leakage (14, 17, 18). The present study showed that CAPD patients, who were high transporters, had more comorbid diseases, a higher proportion of males, lower serum albumin and more comorbid diseases in male patients leads us to speculate that the effect of comorbid diseases on the peritoneal transport rate may explain the relation between men and high transport rate. The CANUSA study showed that increased transport rate was associated with low serum albumin but not with other initial nutritional parameters such as subjective global assessment, percent lean body mass, or normalized protein catabolic rate (23). In addition to comorbid diseases, our study reveals that initial serum albumin concentration is significantly lower in initial H peritoneal transport rate, a finding consistent with previous reports. Coester et al. found that initial D/Pcreat was negatively correlated with initial serum albumin and positively correlated with low hyaluronan (20). Acute

| Transport Groups | H(n=5) | HA(n=12) | LA(n=43) | L(n=0) | p value |
|------------------|--------|----------|----------|--------|---------|
| Age (years)      | 65±12.5 | 58±13.8  | 57±13.4  |        | <0.05   |
| Male (n) %       | 5 (100.0%) | 7 (58.3%) | 17 (39.5%) | <0.05  |
| CD (n) %         | 3 (60.0%) | 6 (50.0%) | 9 (20.9%) | <0.001 |
| Serum albumin (gr/L) | 29±6.0 | 32±3.0  | 37±5.2  | <0.001 |
| D/Pcreat         | 0.84±0.03  | 0.74±0.06  | 0.57±0.05 | <0.001 |
| D4/D0 glucose    | 0.23±0.07  | 0.26±0.04  | 0.42±0.14 | <0.001 |
| Drained volume (ml/24h) | 600±173 | 800±268  | 1016±355 | <0.001 |

Table 5. Clinical Characteristics of Four Transport Groups of CAPD patients. Legend: H=high transporter; HA=high-average transporter; LA=low-average transporter; L=low transporter; CD=comorbid disease; D4/P4Creat =dialyt... to-plasma creatinine concentration ratio at 4 hours of dwell; D4/D0 glucose = ratio of dialysate glucose concentration at 4 hours and at 0 dwell time; Values are express as mean ± standard deviation except for gender, diabetes mellitus, CVD and respiratory which are absolute frequencies and percentages;
and chronic infections and inflammation are present in a large proportion of predialysis patients, and serum albumin is generally accepted as an indicator of inflammation (28). Cueto-Manzano and Correa-Rotter showed that diabetes mellitus was significantly more frequent in high transporters, and was the most important risk factor for mortality on CAPD (25). In the present study, however, we found no significant difference in the proportion of diabetics among different transport groups. Some diabetic patients had more than one comorbid disease. The high rate of comorbid disease in diabetes explains why diabetes is not an independent risk factor for mortality, while CVD and respiratory disease are (29). Nutritional problems were common among PD patients (19). They may be caused by poor appetite, inadequate food intake, insufficient dialysis, and protein loss through the peritoneal membrane. The role of inflammation in connection with malnutrition and atherosclerosis has been recognized only in recent years (30). Low albumin is a strong predictive factor for mortality in CAPD (31). Thus, it seems unlikely that inadequate dialysis would have caused deterioration of the nutritional status.

6. CONCLUSION

The proper classification of patient peritoneal transport type is an important issue in the practice of peritoneal dialysis. Our findings are indicated that peritoneal solute transport rate (PSTR) of small solute, which was evaluated measuring dialysate/plasma ratio of creatinine (D/P creat ) increased over time on peritoneal dialysis. In the same time, there were significantly decreased in the parameters of dialysis adequacy (total weekly Kpt/V urea and total weekly creatinine clearance CcprT) in long term peritoneal dialysis patients. The patients classified as high transporters have more comorbid diseases, lower initial serum albumin, lower D4/D0 glucose, lower drained volume and a higher mortality risk than patients classified in other transport categories. The increased PSTR (based on small solute transport) may indicate different mechanisms of solute transport, depending on the moment when it is evaluated. In summary, our findings indicate that peritoneal solute transport increase over time on PD, and are closely interrelated.

• Declaration of Patient Consent: The authors certify that they obtained all appropriate patient consent forms.
• Authors contribution: Each author were included in all steps of preparation this article. Final proof reading was made by the first author.
• Conflict of interest: None declared.
• Financial support and sponsorship: Nil.

REFERENCES

1. Korevaar JC, Jansen MA, Dokker FW, Jager KJ, Boeschoten EW, Krediet RT et al. Netherlands Cooperative Study on the Adequacy of Dialysis Study Group. When to initiate dialysis: Effect of proposed US guide-lines on survival. Lancet. 2001; 538: 1046-1050.
2. Van Biesen W, Vanholder R, Lameire N. The role of peritoneal dialysis as the first-line renal replacement modality. Perit Dial Int. 2000; 20: 375–383.
3. Hung KY, Huang JW, Tsai TJ, Chen WY. Natural changes in peritoneal equilibration test results in continuous ambulatory peritoneal dialysis patients: a retrospective seven year cohort survey. Artif Organs. 2000; 24: 261-264.
4. Wang T, Heimbürger O, Waniekiewski J, Bergström J, Lindholm B. Increased peritoneal permeability is associated with decreased fluid and small solute removal and higher mortality in CAPD patients. Nephrol Dial Transplant. 1998; 13: 1242-1249.
5. Lameire N, van Biesen W. Importance of blood pressure and volume control in peritoneal dialysis patients. Perit Dial Int. 2001; 21: 206–211.
6. Konings CJ, Kooman JP, Schonk M, Dammers R, Cheriex E, Meulemans APP et al. Fluid status, blood pressure, and cardiovascular abnormalities in patients on peritoneal dialysis. Perit Dial Int. 2002; 22: 477–487.
7. Plum J, Schoeniege G, Kleophas W, Kulas W, Steffens F, Azem A et al. Comparison of body fluid distribution between chronic haemodialysis and peritoneal dialysis patients as assessed by biophysical and biochemical methods. Nephrol Dial Transplant. 2001; 16: 2378–2385.
8. Enía G, Mallamaci F, Benedetto FA, Panuccio V, Parlongo S, Cutrupi S et al. Long-term CAPD patients are volume expanded and display more severe left ventricular hypertrophy than haemodialysis patients. Nephrol Dial Transplant. 2001; 16: 1459–1464.
9. Kok M, Toprak A, Tezcan H, Bihorac A, Akoglu E, Ozener IC. Uncontrolled hypertension due to volume overload contributes to higher left ventricular mass index in CAPD patients. Nephrol Dial Transplant 2002; 17: 1661–1666.
10. Twardowski ZJ, Nolph KD, Khanna R, Prowant BF, Rayan LP, Moore HJ et al. Peritoneal equilibration test. Perit Dial Bull. 1987; 7: 138–147.
11. International Society for Peritoneal Dialysis (ISPD) and hoc committee on ultrafiltration management in peritoneal dialysis. Perit Dial Int. 2000; 20 (Suppl 4): S3-S4.
12. Smith W, Schouten N, van de Berg, Langedijk M, Struijk DG, Krediet RT. Analysis of prevalence and causes of ultrafiltration failure during long-term peritoneal dialysis: a cross-sectional study. Perit Dial Int. 2004; 25: 562–670.
13. Coester A, Smit W, Struijk D, Pannekeet MHD, Krediet R. Longitudinal Analysis of Solute Transport in Peritoneal Dialysis Patients: The Conventional Versus a More Biocompatible PD Solution. Perit Dial Int. 2009; 29 (Suppl 2): 90–95.
14. Balasubramaniyam R, Nirmala VR, Yogesh V, Sethuraman R, Booma Devi S, Balakrishnan NM and al. Comparison of peritoneal transport characteristics at the second week and at six months of peritoneal dialysis commencement. Indian J Nephrol. 2013; 23(5): 346–350.
15. Kendrick J, Teitelbaum I. Strategies for Improving Long-Term Survival in Peritoneal Dialysis Patients. CJASN. 2010; 5(6): 1123-1131.
16. Struijk DG. Monitoring of the peritoneal membrane. Nephrol Dial Transplant. 2008; (Suppl 4): 29–55.
17. Johansson AC, Haraldsson B. Physiological properties of the peritoneum in an adult peritoneal in an adult peritoneal dialysis population over a three year period. Perit Dial Int. 2006; 26: 482–489.
18. Jones SA, Horiiuchi S, Topley N, Yamamoto N, Fuller GM. The soluble interleukin 6 receptor: mechanisms of production and implications in disease. FASEB J. 2001; 15: 45–58.
19. Smith W, Schouten N, van de Berg N, Langedijk M, Struijk Dg, Krediet R.T. Analysis of prevalence and causes of ultrafiltration...
failure during long term peritoneal dialysis: a cross-sectional study. Perit Dial Int. 2004; 25: 562–670.

20. Coester A, Smit W, Struijk D, Pannekeet MHD, Krediet R. Longitudinal analysis of solute transport in peritoneal dialysis patients: The conventional versus a more biocompatible PD solution. Perit Dial Int. 2009; 29 (Suppl 2): 90–95.

21. Hwang YH, Son MJ, Yang J, Kim K, Chung W, Joo KV et al. Effects of interleukin–6 T15A single nucleotide polymorphism on baseline peritoneal solute transport rate in incident peritoneal dialysis patients. Perit Dial Int. 2009; 29(1): 81–88.

22. Lopez EG, Carrero JJ, Suliman E, Linholm B, Stenvinkel P. Risk factors for cardiovascular disease in patients undergoing peritoneal dialysis. Perit Dial Int. 2007; 27 (Suppl 2): S205–S209.

23. Churchill DN, Thorpe KE, Nolph KD, Keshaviah PR, Oreopoulos DG, Page D. Increased peritoneal membrane transport is associated with decreased patient and technique survival for continuous peritoneal dialysis patients. The Canada-Usa (CANUSA) Peritoneal Dialysis Study Group. J Am Soc Nephrol. 1998; 9: 1285–1292.

24. Reyes F, Bajo MA, Hevia C, del Peso G, Ros S, de Miguel AG et al. Inherent high peritoneal transport and ultrafiltration deficiency: their mid-term clinical relevance. Nephrol Dial Transplant. 2007; 22(1): 218–223.

25. Cueto-Manzano AM, Correa-Rotter R. Is high peritoneal transport rate an independent risk factor for CAPD mortality? Kidney Int. 2000; 57: 314–320.

26. Yang X, Fang W, Bargman JM, Oreopoulos DG. High Peritoneal permeability is not associated with higher mortality or technique failure in patients on automated peritoneal dialysis. Perit Dial Int. 2008; 28: 82–92.

27. Devuyst O, Topley N. Peritoneal membrane transport: Driving under influence. Perit Dial Int. 2006; 26: 55–37.

28. Kolesnyk I, Noordzij M, Dekker FW, Boeschoten EW, Krediet RT. A positive effect of A II inhibitors on peritoneal membrane function in long-term PD patients. Nephrol Dial Transplant. 2009; 24(1): 272–277.

29. Abdu A, Ladeira N, Naidoo S, Naicker S. The nutritional status of continuou ambulatory peritoneal dialysis patients at a Johannesburg hospital. SAJCN. 2011; 24(3): 150–153.

30. Rao P, Reddy GC, Kanagasabapathy AS. Malnutrition-inflammation-atherosclerosis syndrome in Chronic Kidney disease. Indian J Clin Biochem. 2008; 23(3): 209–217.

31. Lambie M, Chess J, Donovan KL, Kim JL, Do YJ, Lee HB, et al. Indipendent effects of sistemic and peritoneal inflammamton on peritoneal dialysis survival. J Am Soc Nephrol. 2013; 24: 2071–2080.