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Peritoneal Transport Characteristics Among Pakistani Patients Undergoing Peritoneal Dialysis

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Abstract

Background: The peritoneal membrane acts as a biological filter to remove solutes and fluids during peritoneal dialysis, a well-known kind of renal replacement treatment. Dialysis prescriptions and clinical results are directly influenced by the four transport categories that the peritoneal equilibration test assigns to patients: low, low-average, high-average, and high. The published literature still lacks population-specific transport data from Pakistan.

Objective: To determine the distribution of peritoneal transport types among Pakistani patients undergoing peritoneal dialysis and to evaluate the demographic, clinical, and biochemical variables associated with transport status.

Materials and Methods: Four tertiary care hospitals in Lahore, Pakistan, Bahria international hospital ,Fatima memorial hospital , Ali Fatima hospital and Omar Hospital participated in a multicenter, cross-sectional, observational study. One hundred adult patients receiving continuous ambulatory peritoneal dialysis underwent a standard peritoneal equilibration test six weeks after dialysis began. Transport categorization was done using the Twardowski criterion and the 4-hour dialysate-to-plasma creatinine ratio. Biochemical and clinical parameters were recorded and compared across transport groups using one-way ANOVA and Pearson chi-square tests.

Results: High-average and high transporters collectively constituted 77% of the study population (57% and 20%, respectively). Older age ($p = 0.02$), lower body mass index ($p = 0.02$), diabetic nephropathy ($p = 0.03$), hypoalbuminemia ($p < 0.001$), raised C-reactive protein ($p < 0.001$), and decreased net ultrafiltration volume ($p < 0.001$) were all substantially correlated with higher transport status.

Conclusion: A marked predominance of high peritoneal transport phenotypes was identified in this Pakistani population, attributed to the compounding influence of diabetic nephropathy, systemic inflammation, and nutritional deficits. These findings underscore the need for transport-guided dialysis prescription in this clinical setting.

Keywords:

Peritoneal dialysis; peritoneal equilibration test; peritoneal transport; dialysate-to-plasma creatinine ratio; end-stage kidney disease; Pakistan; continuous ambulatory peritoneal dialysis.

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Introduction

An estimated 697 million people worldwide suffer from chronic kidney disease, and over a million fatalities are attributed to kidney failure each year.[1,2] This represents a growing global public health

burden. Because there is no national renal registry, the burden of end-stage renal disease (ESRD) in Pakistan is significant and difficult to measure, yet available evidence consistently demonstrates a rising incidence driven predominantly by diabetic nephropathy and hypertensive nephrosclerosis. [1,3] Peritoneal dialysis (PD), a popular and affordable type of renal replacement therapy, uses the peritoneal membrane as a biological semi-permeable barrier to remove excess fluid and uremic solutes.[4] In resource-limited settings such as Pakistan, PD offers particular advantages over haemodialysis in terms of lower infrastructure requirements, reduced cost, and preservation of residual renal function, yet it remains significantly underutilized. [5,6]

The characterization of individual peritoneal membrane transport properties is regarded as a fundamental principle for prescribing and adequately prescribing peritoneal dialysis. The main tool for this measurement is still the peritoneal equilibration test (PET), which was first reported by Twardowski et al. in 1987 and subsequently covered in the literature.[7] The PET of solute transfer across the peritoneal membrane was computed using the dialysate to plasma creatinine ratio at four hours. Four transport classes were then established for the patients: low, low-average, high-average, and high transporters. According to current International Society of Peritoneal Dialysis (ISPD) guidelines, the PET should be performed six to twelve weeks after the onset of PD, with additional testing being performed at the clinician's discretion.[8] The high-peritoneal transport status is linked to a rapid glucose uptake, low ultrafiltration capacity, faster peritoneal protein expenditure, and high probability of technical failure and peritonitis.[9,10]

The characteristics of peritoneal transport exhibit significant ethnic differences, clinical comorbidity, and geographical differences. South and South East Asian studies suggest that non-Caucasian groups have a higher baseline transport rate than their Western counterparts, but population-based data on Pakistan are still absent in the literature.[11] In the absence of local reference data, dialysis prescriptions in Pakistani patients can be poorly optimised to the currently dominant membrane phenotype. To determine the distribution of peritoneal type of transport among patients with PD undergoing treatment in four tertiary care hospitals in Lahore, Pakistan, and to determine the biochemical, clinical, and demographic variables associated with the transport status, this was conducted.

Methods

One hundred adult patients with end-stage renal disease who had begun peritoneal dialysis participated in the trial. The IRB approval was obtained via letter # IRBEC/BIH/63-205, Dated 02-06-2025. The four participating centers'(Bahria international hospital ,Fatima memorial hospital , Ali Fatima hospital and Omar Hospital) peritoneal dialysis programs were used for patient selection. To be eligible, patients had to have been on continuous ambulatory peritoneal dialysis (CAPD) for at least six weeks before the peritoneal equilibration test (PET), and must have an intact peritoneal dialysis catheter without any known mechanical complications. Patients were required to be clinically stable at the time of the PET, defined as the absence of active peritonitis, systemic infection, or acute hospitalization within the four weeks preceding the test.

If a patient had an episode of peritonitis within four weeks before the planned PET, they were not allowed to continue in the trial, as peritoneal infection is well recognized to transiently and significantly alter membrane transport characteristics. Additional exclusion criteria included the presence of malignancy, liver cirrhosis, active tuberculosis, or a history of prior renal transplantation. Peritoneal membrane function may be confused by prior exposure to hemodialysis as the first modality of renal replacement therapy, as well as other factors. Patients with incomplete PET data or those who did not fulfil the minimum six-week post-initiation requirement were also excluded.

The peritoneal equilibration test was performed on all enrolled patients six weeks after peritoneal dialysis started, in accordance with the International Society for Peritoneal Dialysis (ISPD) guidelines, which specify that the first PET should be performed between four and eight weeks after PD commencement. This timing was selected to allow sufficient stabilisation of the peritoneal membrane following catheter placement and initial dialysate exposure, while avoiding the confounding influence of early post-insertion inflammatory changes.

The standard PET protocol was followed at all participating centers to ensure uniformity and comparability of results. On the evening preceding the PET, patients performed a standard overnight dwell using 2 liters of 2.27% glucose-based peritoneal dialysis solution. On the test morning, patients reported to the PD clinic, and the overnight dwell was drained completely in the sitting position over a minimum of 20 minutes. A fresh 2-litre exchange of 2.27% glucose peritoneal dialysis solution was then infused over approximately 10 minutes, with the patient ambulating during the first two minutes of the infusion to guarantee that the dialysate is sufficiently mixed throughout the peritoneal cavity.

Dialysate samples were collected at 0 hours (immediately following infusion, after the first 100 mL had been infused and reinfused to mix the dialysate), at 2 hours, and at 4 hours of dwell time. A simultaneous blood sample was obtained to measure plasma creatinine and glucose at the two-hour mark. The dialysate was fully drained while seated at the end of the 4-hour dwell, and the total drained volume was measured to determine the net ultrafiltration volume. All dialysate and plasma samples were processed and analysed in the clinical biochemistry laboratories of the respective hospitals using standard validated laboratory methods.

Solute migration across the peritoneal membrane was measured using two major principal equilibration ratios. The dialysate/plasma creatinine ratio (D/P creatinine) was computed by dividing the dialysate creatinine concentration at 4 hours by the plasma creatinine concentration at the same time. The dialysate glucose ratio (D/D_0 glucose) was computed by dividing the dialysate glucose level at 4 hours by the initial dialysate glucose level at 0 hours. The two ratios were used to categorize the different peritoneal transport types of each patient based on the standardized reference curves.

As determined by their 4-hour D/P creatinine ratio, the patients were categorized into four groups: low transporters (D/P creatinine $\leq$0.49), low-average transporters (D/P creatinine 0.50-0.64), high-average transporters (D/P creatinine 0.65-0.81), and high transporters (D/P creatinine 0.82 and above). Another

functional measure of the peritoneal fluid transport capacity was the total volume evacuated at the conclusion of the 4-hour stay, less the 2-liter infused volume.

To make data capture standardised, structured proformas were used at all four centres. The variables recorded were sex and age, which were categorized into 31-40, 41-5,0 and 51-60 years, and body mass index, which was obtained by dividing weight (kg)/height² (m^2). The clinical data included comorbidities (diabetes mellitus, hypertension, cardiovascular disease) and the cause of end-stage renal disease. Peripheral vascular disease, heart failure, cerebrovascular accidents, and ischemic heart disease were used to determine cardiovascular disease. After fasting before the test's start, venous samples were taken the morning of the peritoneal equilibration test. All hospital labs used proven methods to study serum albumin, hemoglobin, creatinine, blood urea nitrogen, C-reactive protein, phosphorus, and intact parathyroid hormone as biochemical variables.

Statistical Analysis: To analyze the data, SPSS version 26 was utilized. While categorical variables were represented by numbers and percentages, continuous variables were summarized by mean and standard deviation. The Shapiro-Wilk test was used to see if it was normal. Analysis of variance was performed on continuous variables in relation to transit categories and categorical variables in connection to categorical variables using Fisher's exact test or Pearson chi-square test, respectively. All analyses were considered statistically significant if p was less than 0.0,5 and there were no missing values that required imputed values.

Results

There was female dominance, with 57% (n = 57) of patients being female and 43% (n = 43) male. Table 1 displays all of the baseline characteristics.

Based on 4-hour D/P creatinine, 17% were low-average, 6% were low, 57% were high-average, and 20% were high transporters (77% overall). The D/P creatinine and D/D0 glucose averages were 0.71±0.12 and 0.34±0.10, respectively. Net ultrafiltration declined across categories ($p<0.001$), from 618±138 mL in low transporters to 208±126 mL in high transporters at 4 hours (Table 2).

Across transport categories, age distribution differed significantly ($p=0.02$), with high transporters concentrated in 51 – 60 years and none in 31 – 40 years. Body mass index declined with higher transport status (25.8±3.2 to 21.4±3.4 kg/m^2, $p=0.02$), and diabetes prevalence increased (33.3% to 70.0%, $p=0.03$). While creatinine ($p=0.02$) and blood urea nitrogen ($p=0.04$) increased, serum albumin decreased, and C-reactive protein increased (both $p<0.001$). There was no significant correlation between cardiovascular disease, hypertension, or sex (Table 3).

Table 1 shows the study population's baseline sociodemographic, clinical, and biochemical characteristics (n = 100).

Parameters	Frequency (n)	Percentage (%)
Gender		
Male	43	43.0%
Female	57	57.0%
Age Group (years)		
31 – 40	12	12.0%
41 – 50	56	56.0%
51 – 60	32	32.0%
Type of Transporter		
Low transporter	6	6.0%
Low-average transporter	17	17.0%
High-average transporter	57	57.0%
High transporter	20	20.0%
Combined high-average + high transporter	**77**	**77.0%**
Combined low + low-average transporter	**23**	**23.0%**
Comorbid Conditions		
Hypertension	82	82.0%
Diabetes mellitus	52	52.0%
Cardiovascular disease	28	28.0%
Dialysis-Related Characteristics		
PD modality: CAPD	100	100.0%
Biochemical Parameters at Time of PET	**Mean ± SD**	
Body mass index (kg/m²)	23.4 ± 3.8	
Serum albumin (g/dL)	3.2 ± 0.6	
Haemoglobin (g/dL)	9.4 ± 1.8	
Serum creatinine (mg/dL)	8.7 ± 2.4	
Blood urea nitrogen (mg/dL)	68.4 ± 18.6	
Serum C-reactive protein (mg/L)	12.4 ± 8.6	
Serum phosphorus (mg/dL)	5.8 ± 1.4	
Intact parathyroid hormone (pg/mL)	382 ± 214	

Discussion

The present study evaluated peritoneal transport characteristics in 100 patients undergoing peritoneal dialysis across four tertiary care centers in Lahore, Pakistan. 77% of the patients were classified as high-average transporters or high transporters, indicating a large majority of higher transport characteristics. This is also significantly skewed to the faster membrane transport than the reference population, of which the high-average and high transporters together represented about 50% of the patients. [12,13] The observation is consistent with a larger trend of non-Caucasian and South-Asian populations, and it seems

that the baseline peritoneal membrane permeability is constitutively lower among Western counterparts.[11]

Given that 52% of the study sample had diabetic nephropathy as an underlying etiology of ESRD, this high-transport predominance can be explained. By encouraging peritoneal neo-angiogenesis and the buildup of advanced glycation products in the sub-mesothelial layer, diabetic microangiopathy raises the D/P creatinine ratio and the functional capillary surface area of the mesenchymal cell layers.[8,14,15] In this research, a statistically significant relationship between diabetes mellitus and a higher transport status ($p = 0.03$) has been observed, which agrees with the findings of other studies performed among the Asian populations of diabetic PD.[10] Diabetes prevalence is high in Pakistan, as it is estimated that about 30 percent of adults in urban areas are affected by the condition, which is why this mechanistic pathway is especially applicable to the specifics of the disease in the country.[5]

Table 2. Distribution of Peritoneal Transport Types and Associated Peritoneal Equilibration Test Parameters (n = 100)

Parameter	Low Transporter (n = 6)	Low-Average Transporter (n = 17)	High-Average Transporter (n = 57)	High Transporter (n = 20)	Total (n = 100)	p-value
Proportion, n (%)	6 (6.0%)	17 (17.0%)	57 (57.0%)	20 (20.0%)	100 (100%)	—
4-hour D/P creatinine ratio, mean ± SD	0.43 ± 0.05	0.57 ± 0.06	0.72 ± 0.05	0.87 ± 0.04	0.71 ± 0.12	< 0.001
D/P creatinine classification threshold	≤ 0.49	0.50 – 0.64	0.65 – 0.81	≥ 0.82	—	—
4-hour D/D_0 glucose ratio, mean ± SD	0.54 ± 0.06	0.47 ± 0.05	0.35 ± 0.07	0.22 ± 0.05	0.34 ± 0.10	< 0.001
4-hour net ultrafiltration volume (mL), mean ± SD	618 ± 138	522 ± 152	376 ± 168	208 ± 126	378 ± 186	< 0.001

The statistically significant biochemical correlate of increased transport status in the study was hypoalbuminemia ($p < 0.00,1$) with mean serum albumin decreasing gradually with increased transporter status, between 3.8 g/dL in low transporters and 2.8 g/dL in high transporters. This observation indicates that there is a bidirectional interaction between peritoneal protein loss and nutritional depletion - an increased membrane permeability leads to increased transperitoneal albumin losses, whereas underlying malnutrition and inflammation cause an independent effect of increasing membrane permeability.[7,16] The similar increase in serum CRP with increasing categories of ascending transport ($p < 0.001$) also supports the view that systemic inflammation is a key determinant of peritoneal transport status in said population. The present ISPD guidelines are specifically aware of this inflammatory-transport interaction and prescribing modification in patients with rapid solute transfer rates to alleviate its clinical impact.[7,17,18] In a recent detailed review by Su, H et.al. the presence of sterile inflammatory response is related to the presence of advance glycation end products with the high glucose

peritoneal dialysate and a possible link to the high CRP levels.[19] We have observed a significant correlation with the Higher CRP levels and higher PET test values. This needs further evaluation in our patients with measurement of various cytokines in future studies.

Table 3: Comparative Evaluation of Clinical, Biochemical, and Sociodemographic Factors Peritoneal Transport Group (n = 100) stratification

Variable	Low (n = 6)	Low-Average (n = 17)	High-Average (n = 57)	High (n = 20)	p-value
Gender, n (%)					
Male	2 (33.3%)	6 (35.3%)	25 (43.9%)	10 (50.0%)	0.58
Female	4 (66.7%)	11 (64.7%)	32 (56.1%)	10 (50.0%)	
Age Group, n (%)					
31 – 40 years	3 (50.0%)	5 (29.4%)	4 (7.0%)	0 (0.0%)	0.02
41 – 50 years	2 (33.3%)	9 (52.9%)	33 (57.9%)	12 (60.0%)	
51 – 60 years	1 (16.7%)	3 (17.6%)	20 (35.1%)	8 (40.0%)	
Body Mass Index (kg/m²), mean ± SD	25.8 ± 3.2	24.6 ± 3.8	23.2 ± 3.6	21.4 ± 3.4	**0.02**
Comorbid Conditions, n (%)					
Hypertension	4 (66.7%)	12 (70.6%)	48 (84.2%)	18 (90.0%)	0.19
Diabetes mellitus	2 (33.3%)	6 (35.3%)	30 (52.6%)	14 (70.0%)	**0.03**
Cardiovascular disease	1 (16.7%)	3 (17.6%)	17 (29.8%)	7 (35.0%)	0.38
Biochemical Parameters, mean ± SD					
Serum albumin (g/dL)	3.8 ± 0.4	3.5 ± 0.5	3.2 ± 0.5	2.8 ± 0.6	**< 0.001**
Haemoglobin (g/dL)	10.4 ± 1.6	9.8 ± 1.7	9.4 ± 1.8	8.8 ± 1.8	0.06
Serum creatinine (mg/dL)	7.2 ± 2.0	7.8 ± 2.2	8.8 ± 2.4	10.1 ± 2.6	**0.02**
Blood urea nitrogen (mg/dL)	58.4 ± 14.8	62.6 ± 16.4	69.2 ± 18.8	76.8 ± 20.2	**0.04**
Serum C-reactive protein (mg/L)	6.4 ± 3.8	9.2 ± 6.4	12.8 ± 8.2	18.6 ± 9.4	**< 0.001**
Serum phosphorus (mg/dL)	5.2 ± 1.2	5.5 ± 1.3	5.8 ± 1.4	6.4 ± 1.5	0.14
Intact parathyroid hormone (pg/mL)	298 ± 168	342 ± 192	386 ± 218	428 ± 242	0.22
PET-Derived Parameters, mean ± SD					
4-hour D/P creatinine ratio	0.43 ± 0.05	0.57 ± 0.06	0.72 ± 0.05	0.87 ± 0.04	**< 0.001**
4-hour D/D_0 glucose ratio	0.54 ± 0.06	0.47 ± 0.05	0.35 ± 0.07	0.22 ± 0.05	**< 0.001**
4-hour net ultrafiltration volume (mL)	618 ± 138	522 ± 152	376 ± 168	208 ± 126	**< 0.001**

The inverse association between BMI and transport status (p = 0.02), with the lowest mean BMI recorded among high transporters (21.4 ± 3.4 kg/m²), is consistent with registry data from Australia and New Zealand demonstrating that lower BMI independently predicts higher peritoneal transport status.[8] In the South Asian context, the generally lean body habitus of the study population may have contributed independently to the skewed transport distribution observed. Similarly, the concentration of patients in the 41 – 60-year age group, particularly among high transporters, reflects the age-related structural changes in peritoneal microvasculature that facilitate more rapid solute equilibration.[4]

From a clinical standpoint, the predominance of high-average and high transporters in this population carries direct prescriptive implications. Rapid peritoneal solute transfer rate patients equilibrate quickly and are vulnerable to ultrafiltration failure, glucose reabsorption, and peritoneal protein losses if treated with conventional CAPD regimens that involve prolonged dwell times. The significantly lower net 4-hour ultrafiltration volumes observed in high transporters (208 ± 126 mL) in this study confirm this functional impairment.[9,14] Given that all patients were receiving CAPD — the most prevalent and accessible PD modality in Pakistan — the appropriateness of current standard dwell prescriptions in high-transport patients warrants re-evaluation. Shorter dwell times, consideration of icodextrin-based solutions for the long exchange, and selective use of automated peritoneal dialysis are evidence-based strategies to mitigate the adverse consequences of fast transport status.[7,8]

This study carries limitations that warrant acknowledgement. The cross-sectional design makes it impossible to evaluate the development of transport status with time, and the lack of longitudinal data on peritonitis, measurement of residual renal functioning, and the description of nutritional data does not allow characterize the transport phenotype in all aspects. The research is limited by the size of the sample, which does not imply the findings to the broader Pakistani PD community, although it may be adequate in a multicentric descriptive study. To ascertain the time course of peritoneal transport and the potential impact of a transport-specific prescription change on the outcome, prospective studies involving nutritional indices, experimental measures of residual kidney functioning, and serial measurements of PET should be carried out in this population in the future.

Conclusion

Peritoneal transport status was high-average and high for 77% of Pakistani patients receiving continuous ambulatory peritoneal dialysis, according to this multicenter study. This distribution is significantly higher than that found in Western populations. The main factors linked to quicker peritoneal transfer were diabetic nephropathy, hypoalbuminemia, systemic inflammation, advanced age, and a lower body mass index. The functional effects of increased membrane permeability in this population are confirmed by significantly lower net ultrafiltration volumes in high transporters. In order to improve dialysis adequacy and long-term patient outcomes, these findings emphasize the clinical significance of routine peritoneal equilibration test performance at dialysis initiation and the necessity of transport-guided prescription optimization in Pakistani patients, including consideration of shorter dwell times and icodextrin-based solutions.

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