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Original Article

The impact of sub-clinical over-hydration on left ventricular mass in peritoneal dialysis patients

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Abstract: Objective: Left ventricular hypertrophy (LVH) represents a major predictor of the development of cardiovascular (CV) complications. Over-hydration (OH) is an important uremic risk factor associated with LVH and increased CV morbidity and mortality in peritoneal dialysis (PD) patients. In the present study we evaluated the prevalence of sub-clinical OH (SCOH) among PD patients and its effects on left ventricular mass (LVM). Methods: In this cross sectional study hydration status, blood pressure, glucose load, systemic inflammation and LVM were evaluated in 43 clinically stable patients on maintenance PD for 24-76 months. The hydration status was assessed by whole-body bio-impedance spectroscopy (BIS). Peripheral edema and any evidence of pulmonary congestion were considered clinical signs of OH. Results: OH ≥ 1.5 L was detected in 26 (60.5%) of the study participants; the OH in 19 (73.1%) of them was sub-clinical. Only 23.5% (4/17) of patients with OH < 1.5 L had LVH compared to 68.4% (13/19) of those with SCOH ≥ 1.5 L (P = 0.007). Compared to patients with OH < 1.5 L, patients with SCOH ≥ 1.5 L had higher levels of blood pressure, peritoneal glucose load, plasma brain natriuretic peptide, high sensitive C-reactive protein, interleukin-6 and LVMI; and lower levels of serum albumin (P < 0.001). No significant differences were found between patients with clinical OH or SCOH with OH ≥ 1.5 L. Conclusions: SCOH is highly prevalent among PD patients and may contribute to the development of LVH. Considering the poor prognosis associated with over-hydrated PD patients, periodic assessment of hydration status using accurate BIS is suggested.

Keywords: Peritoneal dialysis, over-hydration, fluid overload, blood pressure, inflammation, left ventricular mass

Introduction

Cardiovascular (CV) complications are the main cause of morbidity and mortality in dialysis patients [1-4]. Traditional, uremic and novel risk factors have been shown to contribute to early coronary atherosclerosis in peritoneal dialysis (PD) patients [4, 5]. Left ventricular hypertrophy (LVH) represents a major predictor of the development of CV events [3-5].

Over-hydration (OH) is an important and treatable uremic risk factor among dialysis patients and associated with increased morbidity and mortality rates [6, 7]. Moreover, OH is considered an essential cause of elevated blood pressure, plasma brain natriuretic peptide (BNP) and of inflammation marker levels in dialysis patients [8-11]. Hypertension is recognized to be associated with the development of LVH [12, 13]. BNP is considered a cardiac biomarker related to LVH and contributes to the evolution of atherosclerosis and CV disease in PD patients [8-11]. Chronic inflammation is a common novel risk factor in dialysis patients that is considered to be a powerful predictor of the development of LVH and CV disease [14, 15]. The inflammatory process stimulated by OH increases peritoneal membrane permeability and fluid accumulation [16, 17].

Although the roles of OH, glucose load, and inflammation in CV morbidity and mortality in PD patients are recognized, CV disease is still frequently under-diagnosed and under-treated in this population. "Dry weight", which is the

Table 1. Characteristics of the study population (n = 43)

Variable	Mean and SD or % (number)
Age (year)	59.3 ± 11.6
Female % (n)	53.5 (23)
Diabetes mellitus % (n)	46.5 (20)
Hypertension % (n)	58.1 (25)
BMI > 30 kg/m^2 % (n)	34.9 (15)
Dialysis vintage (months)	37.3 ± 12.4
Daily urine volume (ml/day)	756.8 ± 116.3
Residual renal function (ml/min)	7.3 ± 2.4
Smoking % (n)	7 (3)
CAPD % (n)	53.5 (23)
APD % (n)	46.5 (20)
Kt/V	2.1 ± 0.3
High average transporters % (n)	55.8 (24)
low average transporters % (n)	44.2 (19)
Received loop diuretics % (n)	88.4 (38)
Received calcium channels blockers % (n)	41.9 (18)
Received ACEIs/ARBs % (n)	11.6 (5)
Other antihypertensive agents % (n)	20.9 (9)
Primary renal disease:	
Diabetes mellitus % (n)	46.5 (20)
Hypertension % (n)	20.9 (9)
Chronic glomerulonephritis % (n)	11.6 (5)
Adult polycystic kidney disease % (n)	9.3 (4)
Unknown etiology	11.6 (5)

Data presented as mean ± SD or % (number of patients). BMI = body mass index; CAPD = continuous ambulatory peritoneal dialysis; APD = automated peritoneal dialysis; Kt/V is a dimensionless index that measures the fractional urea clearance during dialysis; High transporters have high peritoneal membrane permeability or high effective peritoneal membrane area; and low transporters have low peritoneal membrane permeability or low effective peritoneal membrane area; Thus, high average/low average transporters have intermediate values compared with high or low transporters; ACEIs = angiotensin converting enzyme inhibitors; ARBs = angiotensin receptor blockers.

body weight when all or most excess fluid has been removed, changes frequently, due to variations in hydration status. In practice, dry weight is usually determined clinically on a trial and error basis without utilizing accurate methods such as whole-body bioimpedance spectroscopy (BIS). In addition, hydration status is not always re-evaluated periodically. Often, OH is sub-clinical and undiagnosed through the periodic routine clinical examination of PD patients. To our best knowledge we are not aware of studies that targeted to evaluate the prevalence and the effects of sub-clinical overhydration (SCOH) on CV complications in PD patients. In the present study we evaluated the prevalence of SCOH among PD patients and its effects on left ventricular mass (LVM) in this population.

Material and methods

Study population

In this cross sectional study, volume status, LVM, and levels of plasma BNP, blood pressure, plasma high sensitive C-reactive protein (hsCRP), interleukin 6 (IL-6), and serum albumin were evaluated in 43 clinically stable patients on maintenance PD for 24-76 months. The study protocol was approved by the Medical Ethics Committee of Western Galilee Hospital, Nahariya, Israel. All patients signed a written informed consent form before participating in the study. Age under 18 years, pregnancy, psychiatric disorders, active coronary artery disease, heart failure (New York Heart Association [NYHA] class III or IV), any evidence of infection in the past three months, immunosuppressive therapy, liver cirrhosis, malignancy, patients with vascular stents, pacemakers, defibrillators, artificial joints, pins or limb amputations, were all considered exclusion criteria. All participants followed their usual recommended diet and continued their regular medications and PD regimen. The target HbA1c (< 8%) was achieved in patients with diabetes mellitus by adjusting insulin doses as needed. Likewise, adjustments were made in antihypertensive drug doses, with the aim of achieving the blood pressure goal of < 140/90. All patients participating in the study received only glucose based PD solutions. All patients on automated PD modality were with dry abdomen during the day.

Blood pressure measurements

Blood pressure was evaluated using the Mobil-O-Graph device for 24-hour ambulatory blood

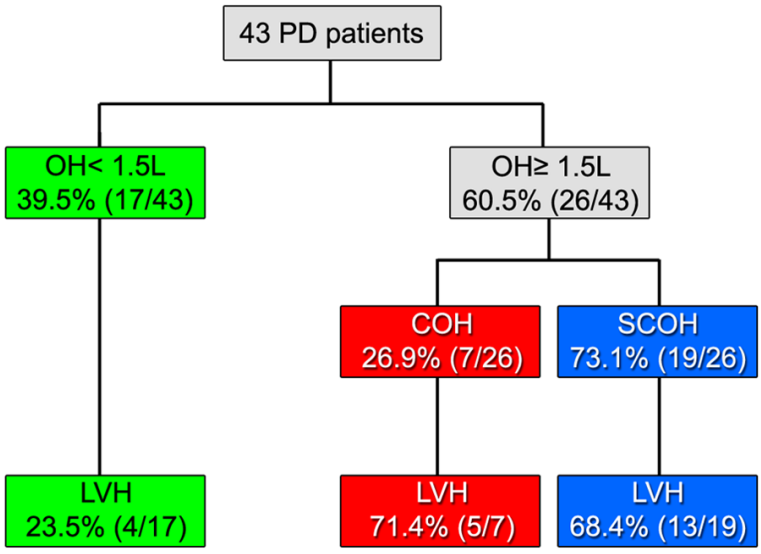

Figure 1. The over-hydration (OH) and the presence of left ventricular hypertrophy (LVH) in a cohort of peritoneal dialysis (PD) patients. OH was detected in 60.5% of PD patients. The majority of these patients (73.1%) had no clinical evidence of fluid overload. Moreover, LVH, which is considered a major predictor of the development of CV events, was detected in most patients (68.4%) who were sub-clinically over-hydrated compared to only 23.5% of those with OH < 1.5 L (P = 0.007).

pressure monitoring (Manufacture: Industrielle Entwicklung Medizintechnik GmbH, D-52222 Stolberg, Germany).

Volume status assessment

Volume status was assessed by BIS, Fresenius Medical Care Body Composition Monitor (BCM) device, Bad Homburg, Germany [13]. Fluid excess of ≥ 1.5 L detected by BIS was considered OH. Peripheral edema and pulmonary congestion were considered clinical signs of OH.

Peritoneal glucose load determination

Peritoneal glucose load (PGL) was calculated according to a PGL index (PGLI) that was defined as the total net glucose content (g) in the daily PD prescription divided by the dry body weight (kg), as assessed by the BCM device.

Left ventricular mass calculation

LVMI was calculated by the Devereux formula [18]:

$$LVMI\left(\frac{g}{m^2}\right) = \{0.8[(IVST + LVPWT + LVEDD)^3 - (LVEDD)^3] + 0.6\}/Bodysurface$$

[Interventricular septal thickness (IVST), left ventricular posterior wall thickness (LVPWT) and left ventricular end diastolic diameter (LVEDD)]. LVH is defined by an increase in LVMI ≥ 95 g/m^2 in women and ≥ 115 g/m^2 in men [19-21].

Statistical analysis

Quantitative variables were described using means and standard deviations. Qualitative variables were described using frequencies and percentages. Quantitative variables were compared among groups by the paired t-test or Wilcoxon signed ranks test. Qualitative variables, such as frequencies and percentages, were compared by Chi square test. Correlations between OH and levels of blood pressure, plasma BNP, hsCRP, IL-6, serum albumin, and LVMI were described by the Pearson correlation coefficient test. A logistic regression with a stepwise selection model was applied to identify factors that predict the presence of LVH. Statistical analysis was carried out using SPSS statistical package (Version 19) and *p*-values of 0.05 were considered to be significant.

Results

The characteristics of the study population are summarized in **Table 1**. Diabetes mellitus and hypertension were the most common primary renal diseases [46.5% (20/43) and 20.9% (9/43), respectively]. 88.4% (38/43) received loop diuretics, 41.9% (18/43) received calcium channel blockers, 11.6% (5/43) received angiotensin inhibition agents, and 20.9% (9/43) received other antihypertensive agents.

OH ≥ 1.5 L was detected in 60.5% (26/43) of participating patients (**Figure 1**). Of them 73.1% (19/26) had SCOH ≥ 1.5 L (**Figure 1**). LVH was detected in 68.4% (13/19) of patients with SCOH ≥ 1.5 L compared to only 23.5% (4/17) of those with OH < 1.5 L (P = 0.007) (**Table 2**; **Figure 1**).

OH was positively and significantly correlated with mean 24 hour SBP (r = 0.68, P < 0.001),

Table 2. Comparison between patients with OH <1.5 L and patients with OH ≥ 1.5 L

	OH < 1.5 L (n = 17)	OH ≥ 1.5 L (n = 26)				
		COH (n = 7)	SCOH (n = 19)			
Variables				P*	P**	P***
Diabetes % (n)	47.1 (8/17)	42.9 (3/7)	47.4 (9/19)	0.985	0.854	0.838
DUV (ml/day)	787.7 ± 139.3	771.5 ± 119.4	742.8 ± 128.6	0.784	0.323	0.606
RRF (ml/min)	7.7 ± 5.6	7.8 ± 6.3	7.3 ± 4.9	0.971	0.821	0.843
BNP (pg/ml)	156.0 ± 39.4	664.2 ± 63.2	676.9 ± 44.9	< 0.001	< 0.001	0.605
24 h SBP (mmHg)	135.6 ± 4.7	150.1 ± 7.3	148.1 ± 6.1	< 0.001	< 0.001	0.508
24 h DBP (mmHg)	79.1 ± 4.6	91.7 ± 5.1	92.3 ± 4.3	< 0.001	< 0.001	0.776
HbA1c (%)	7.2 ± 0.9	7.6 ± 1.3	7.4 ± 1.0	0.434	0.533	0.700
PGLI (g/kg/day)	2.2 ± 0.5	4.1 ± 0.8	4.3 ± 0.6	< 0.001	< 0.001	0.528
Plasma hsCRP (mg/dl)	2.4 ± 1.0	15.9 ± 8.9	17.2 ± 10.0	0.007	< 0.001	0.759
Plasma IL-6 (pg/ml)	0.4 ± 0.2	6.5 ± 4.7	7.2 ± 3.1	0.014	< 0.001	0.694
Serum albumin (g/dl)	3.9 ± 0.4	3.2 ± 0.4	3.3 ± 0.3	0.001	< 0.001	0.528
LVMI (gr/m^2)	92.4 ± 23.2	155.6 ± 62.4	153.4 ± 42.7	0.040	< 0.001	0.927
LVH % (n)	23.5 (4/17)	71.4 (5/7)	68.4 (13/19)	0.061	0.007	0.882

Data presented as mean ± SD or % (number of patients). OH = over-hydration, COH = clinical over-hydration, SCOH = sub-clinical over-hydration, P* = statistical significance between patients with OH < 1.5 L and patients with COH ≥ 1.5 L, P** = statistical significance between patients with OH < 1.5 L and patients with SCOH ≥ 1.5 L, P*** = statistical significance between patients with COH ≥ 1.5 L and patients with SCOH ≥ 1.5 L, DUV = daily urine volume, RRF = residual renal function, BNP = plasma brain natriuretic peptide, 24 h SBP = mean 24 hour systolic blood pressure, 24 h DBP = mean 24 hour diastolic blood pressure, PGLI = peritoneal glucose load index, hsCRP = high sensitivity C-reactive protein, IL-6 = interleukin 6, LVMI = left ventricular mass index, LVH = left ventricular hypertrophy.

mean 24 hour DBP (r = 0.51, P = 0.01), PGLI (r = 0.84, P < 0.001), plasma BNP (r = 0.91, P < 0.001), plasma hsCRP level (r = 0.94, P < 0.001) and plasma IL-6 levels (r = 0.92, P < 0.001). OH was negatively and significantly correlated with serum albumin levels (r = - 0.77, P < 0.001). A positive and significant correlation between OH and LVMI (r = 0.76, P < 0.001) was exposed (**Figure 2**).

No differences were found between patients with COH ≥ 1.5 L and those with SCOH ≥ 1.5 L (**Table 2**). Patients with COH or SCOH ≥ 1.5 L had significant higher levels of blood pressure, PGLI, plasma BNP, hsCRP IL-6 levels, and LVMI; and lower levels of serum albumin, compared to those with OH < 1.5 L (**Table 2**).

Discussion

In the present study OH was detected in 60.5% of PD patients. The majority of these patients (73.1%) had no clinical evidence of fluid overload. Moreover, LVH, which is considered a major predictor of the development of CV events [3-5], was detected in most patients (68.4%) who were sub-clinically over-hydrated (**Table 2**; **Figure 1**). In contrast, LVH was detected in only 23.5% of those with OH < 1.5 L. We are unaware of studies that reported such high prevalence of SCOH and investigated a possible association between SCOH and LVH in PD population.

Blood pressure, PGLI values, plasma BNP, hsCRP and IL-6 levels as well as LVMI were higher in patients with SCOH ≥ 1.5 L than in those with OH < 1.5 L (P < 0.001) (**Table 2**). Serum albumin was lower in patients with SCOH ≥ 1.5 L compared to those with OH < 1.5 L. Interestingly, no differences in all tested variables were observed between patients with COH ≥ 1.5 L and those with SCOH ≥ 1.5 L (**Table 2**). This notable finding suggests that the impact of SCOH seem to be similar to the adverse effects of COH on blood pressure, systemic inflammation and LVM. This emphasizes the need for accurate assessment of the hydration status before the onset of clinical manifestations of the fluid excess.

OH was positively and significantly correlated with blood pressure, plasma BNP, hsCRP and IL-6 levels. Serum albumin was negatively correlated with the OH. LVMI was positively correlated with the OH (**Figure 2**).

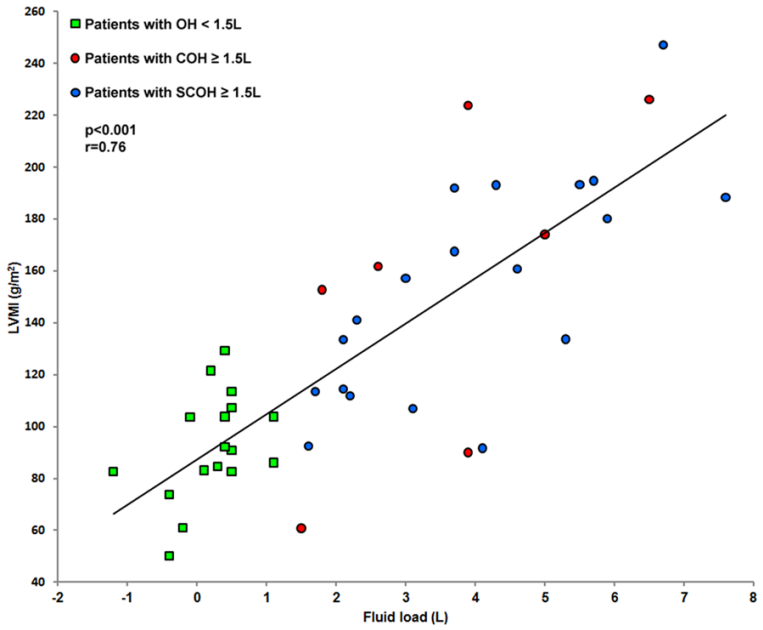

Figure 2. The correlation between the hydration status (fluid load) and left ventricular mass index (LVMI). OH = over-hydration, COH = clinical OH, SCOH = sub-clinical OH. The results revealed a positive and significant correlation between the OH and LVMI.

This study suggests that, even in the absence of clinical signs, SCOH is a common finding among patients on maintenance PD and may contribute to the development of LVH in this population. The contribution of SCOH to LVH may occur through several possible mechanisms. First, OH is considered an essential cause of elevated blood pressure in dialysis patients [8-11], and hypertension is recognized as associated with the development of LVH [12, 13]. Second, OH is also considered an essential cause of elevated plasma BNP [8-11]. Plasma BNP is considered a cardiac biomarker related to LVH, atherosclerosis and CV disease in PD patients [8-10, 13]. Third, OH stimulates the inflammatory process and chronic inflammation is considered a powerful predictor of the development of LVH and CV disease in PD patients [8-11, 14, 15]. Fourth, OH necessitates the utilization of higher concentrations of glucose based dialysis solutions, leading to higher PGLI as it was detected in the patients of this study with OH ≥ 1.5 L. The glucose load contributes to cumulative damage caused to the peritoneal membrane due to long-lasting exposure to glucose, glucose degradation products (GDPs), advanced glycation end products (AGEs), and the non-physiological pH of conventional PD solutions [22-24]. These effects increase fluid accumulation and aggravate the OH leading to the development of LVH [6-11, 13].

Due to the poor prognosis of over-hydrated PD patients, and consequent to the fact that OH can be modified by available treatment strategies, periodic assessment of the hydration status using accurate BIS methods is necessary to detect sub-clinical fluid excess. These strategies should also include reduction of dietary salt and fluid intake, the addition of loop diuretics and assessment of inflammatory status. All these CV risk factors should be identified and treated as early as possible, even if they are sub-clinical, before significant CV complications develop. Current techniques in PD enable achievement of adequate fluid removal, blood pressure control and attenuation of the inflammatory process.

The present study highlights the highly prevalent SCOH among PD patients and its contribution to the development of LVH. Identifying relevant patients and modifying OH may contribute to better PD patient outcomes. The contribution of OH to the development of LVH renders BIS as a simple measurement that represents a potential therapeutic method for the detection of SCOH in PD populations. Periodic monitoring of hydration status using BIS enables physicians to detect SCOH and to perform real-time interventions to decrease the fluid excess and to prevent the development of LVH. This approach to the sub-clinically over-hydrated PD patients may contribute to the improvement of their outcomes.

Limitations

The present study was conducted in one medical center and included a relatively small number of patients. Additional and larger multi-center, randomized control trials are needed to establish the prevalence and impact of SCOH in the development of LVH in PD patients.

Conclusion

SCOH is highly prevalent among PD patients and may contribute to the development of LVH. Considering the poor prognosis associated with over-hydrated PD patients, periodic assessment of hydration status using accurate BIS is suggested.

Disclosure of conflict of interest

None.

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References

[1] Locatelli F, Covic A, Chazot C, Leunissen K, Luno J, Yaqoob M. Hypertension and cardiovascular risk assessment in dialysis patients. Nephrol Dial Transplant 2000; 15: 69-80.

[2] Parikh NI, Hwang SJ, Larson MG, Meigs JB, Levy D, Fox CS. Cardiovascular disease risk factors in chronic kidney disease: overall burden and rates of treatment and control. Arch Intern Med 2006; 166: 1884-1891.

[3] Levy D, Garrison RJ, Savage DD, Kannel WB, Castelli WP. Prognostic implications of echocardiographically determined left ventricular mass in the Framingham Heart Study. N Engl J Med 1990; 322: 1561-1566.

[4] Stenvinkel P, Amann K and Ketteler M. Cardiovascular disease in chronic kidney disease. Comprehensive Clinical Nephrology. 3rd edition. In: Feehally J, Floege J, Johnson RJ, editors. Philadelphia: Mosby Elsevier; 2007. pp. 839-852.

[5] Ebinç FA, Erten Y, Ebinç H, Paşaoğlu H, Demirtaş C, Taçoy G, Mutluay R, Koç E, Derici U, Reis KA, Bali M, Arinsoy T, Sindel S. The relationship among asymmetric dimethylarginine (ADMA) levels, residual renal function, and left ventricular hypertrophy in continuous ambulatory peritoneal dialysis patients. Ren Fail 2008; 30: 401-406.

[6] Wizemann V, Wabel P, Chamney P, Zaluska W, Moissl U, Rode C, Malecka-Masalska T, Marcelli D. The mortality risk of overhydration in haemodialysis patients. Nephrol Dial Transplant 2009; 24: 1574-1579.

[7] Lindley EJ. Reducing sodium intake in hemodialysis patients. Semin Dial 2009; 22: 260-263.

[8] Crepaldi C, Lamas EI, Martino FK, Rodighiero MP, Scalzotto E, Wojewodzka-Zelezniakowicz M, Rosner MH, Ronco C. Bioimpedance and brain natriuretic peptide in peritoneal dialysis patients. Contrib Nephrol 2012; 178: 174-181.

[9] Sav T, Inanc MT, Dogan A, Oymak O, Utas C. Two daytime icodextrin exchanges decrease brain natriuretic peptide levels and improve cardiac functions in continuous ambulatory peritoneal dialysis patients. Nephrology (Carlton) 2010; 15: 307-312.

[10] Konings CJ, Kooman JP, Schonck M, Dammers R, Cheriex E, Palmans Meulemans AP, Hoeks AP, van Kreel B, Gladziwa U, van der Sande FM, Leunissen KM. Fluid status, blood pressure, and cardiovascular abnormalities in patients on peritoneal dialysis. Perit Dial Int 2002; 22: 477-487.

[11] Chan CT, Greene T, Chertow GM, Kliger AS, Stokes JB, Beck GJ, Daugirdas JT, Kotanko P, Larive B, Levin NW, Mehta RL, Rocco M, Sanz J, Schiller BM, Yang PC, Rajagopalan S. Determinants of left ventricular mass in patients on hemodialysis: frequent Hemodialysis Network (FHN) Trials. Circ Cardiovasc Imaging 2012; 5: 251-261.

[12] Nwafor CE, Adebiyi AA, Ogah OS, Falase AO. Relationship between 24-hour blood pressure pattern and left ventricular structure and function in hypertensive Nigerians. Ethn Dis 2013; 23: 474-479.

[13] Voroneanu L, Cusai C, Hogas S, Ardeleanu S, Onofriescu M, Nistor I, Prisada O, Sascau R, Goldsmith D, Covic A. The relationship between chronic volume overload and elevated blood pressure in hemodialysis patients: use of bioimpedance provides a different perspective from echocardiography and biomarker methodologies. Int Urol Nephrol 2010; 42: 789-797.

[14] Monfared A, Salari A, Kazemnezhad E, Lebadi M, Khosravi M, Mehrjardi NK, Rahimifar S, Amini N. Association of left ventricular hypertrophy with high-sensitive C-reactive protein in hemodialysis patients. Int Urol Nephrol 2013; 45: 1679-1686.

[15] van der Walt C, Malan L, Uys AS, Malan NT. Low Grade Inflammation and ECG Left Ventricular Hypertrophy in Urban African Males: The SABPA Study. Heart Lung Circ 2013; 22: 924-929.

[16] Avila-Díaz M, Ventura MD, Valle D, Vicenté-Martínez M, García-González Z, Cisneros A, Furlong MD, Gómez AM, Prado-Uribe MD, Amato D, Paniagua R. Inflammation and extracellular volume expansion are related to sodium and water removal in patients on peritoneal dialysis. Perit Dial Int 2006; 26: 574-580.

[17] Kim SB, Chang JW, Lee SK, Park JS. Acute systemic inflammation is associated with an increase in peritoneal solute transport rate in chronic peritoneal dialysis patients. Perit Dial Int 2004; 24: 597-600.

[18] Devereux RB, Alonso DR, Lutas EM, Gottlieb GJ, Campo E, Sachs I, Reichek N. Electrocardiographic assessment of left ventricular hypertrophy: comparison to necropsy findings. Am J Cardiol 1986; 57: 450-458.

[19] Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, Picard MH, Roman MJ, Seward J, Shanewise JS, Solomon SD, Spencer KT, Sutton MS, Stewart WJ. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr 2005; 18: 1440-1463.

[20] Levy D, Garrison RJ, Savage DD, Kannel WB, Castelli WP. Prognostic implications of echocardiographically determined left ventricular mass in the Framingham Heart Study. N Engl J Med 1990; 322: 1561-1566.

[21] Ghali JK, Liao Y, Simmons B, Castaner A, Cao G, Cooper RS. The prognostic role of left ventricular hypertrophy in patients with or without coronary artery disease. Ann Intern Med 1992; 117: 831-836.

[22] Boulanger E, Moranne O, Wautier MP, Rougier JP, Ronco P, Pagniez D, Wautier JL. Biocompatibility of peritoneal dialysis fluids. Nephrol Ther 2005; 1: 14-22.

[23] Johnson DW, Brown FG, Clarke M, Boudville N, Elias TJ, Foo MW, Jones B, Kulkarni H, Langham R, Ranganathan D, Schollum J, Suranyi MG, Tan SH, Voss D. The effects of biocompatible compared with standard peritoneal dialysis solutions on peritonitis microbiology, treatment, and outcomes: the balANZ trial. Perit Dial Int 2012; 32: 497-506.

[24] Johnson DW, Brown FG, Clarke M, Boudville N, Elias TJ, Foo MW, Jones B, Kulkarni H, Langham R, Ranganathan D, Schollum J, Suranyi MG, Tan SH, Voss D. balANZ Trial Investigators. The effect of low glucose degradation product, neutral pH versus standard peritoneal dialysis solutions on peritoneal membrane function: the balANZ trial. Nephrol Dial Transplant 2012; 27: 4445-4453.