Cardiac morphology and function in patients with and without residual diuresis on hemodialysis

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ABSTRACT

In patients with chronic renal failure on hemodialysis, left ventricular hypertrophy is related to the increase in total peripheral vascular resistance and volume overload. The presence of residual diuresis enables greater control of the volemia of these. We evaluated the morpho-functional changes of the left ventricle in patients with chronic kidney disease on hemodyalisis treatment with and without residual diuresis. A total of 31 non diabetic patients were studied and they were divided into two groups: with residual diuresis (RD+) (n = 17) and without residual diuresis (RD-) (n = 14). In both groups, RD+ *vs*. RD-, using data from a Doppler echocardiogram differences were found, respectively, in the cardiac index (3.9 ± 0.2 *vs*. 3.0 ± 0.2 L/min/m^2; p = 0.0056), systolic index (54 ± 2.9 *vs*. 45 ± 3.3 mL/b/m^2; p = 0.04), end diastolic volume (141 ± 6.7 *vs*. 112 ± 7.6 mL; p = 0.008), end diastolic diameter (52 ± 0.7 *vs*. 48 ± 1.1 mm; p = 0.0072) and total peripheral resistance index (1121 ± 56 *vs*. 1529 ± 111 dyne.sec.cm^{-5}; p = 0.001). RD+ had lower relative wall thickness than RD- (0.38 ± 0.01 *vs*. 0.45 ± 0.01; p = 0.0008). The ejection fraction and the left ventricular mass index were similar in both groups. The urinary 24-hour volume correlated with the relative wall thickness (r = -0.42; p = 0.0186) and with peripheral resistance index (r = -0.48; p = 0.0059). In conclusion, there were distinct ventricular geometric patterns and different functional performances between RD+ and RD- groups. The presence of residual diuresis can be responsible by these modifications in systolic function.

Keywords: chronic kidney failure, ventricular remodelling, stroke volume.

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INTRODUCTION

Although glomerular filtration rate is rather low in patients with chronic kidney disease (CKD), daily residual diuresis volumes can vary from anuria to polyuria in different individuals. The preservation of residual diuresis (RD) assists in the purification of low- to medium-molecular-weight substances, allowing for even greater liquid removal[1] and improvement of the patient's nutritional state[2,3] and quality of life,[4] in addition to maintaining the endocrine functions of the kidney.[5] During the conservative management of patients with CKD,[6] it was observed that the decline in the glomerular filtration rate was associated with left ventricular hypertrophy (LVH).[7-11] The presence of LVH, in turn, constitutes an important independent factor for cardiovascular risk in patients with CKD.[7,8,12,13] Patients in renal replacement therapy (stage V)[6] may have larger or smaller residual renal function (RRF) declines depending on the diastolic method used.[14] Thus, patients on hemodialysis (HD) had more rapid reductions in their RRF than those on peritoneal dialysis (PD).[14-17] The progressive reduction in renal function is associated with LVH and greater cardiovascular mortality in PD patients.[12,18,19] In various studies, the presence of LVH was related to hemodialysis treatment;[9,10,12,20,21] however, few studies have reported a relationship between LVH and the morphological and functional aspects of the left ventricle with different volumes of residual diuresis. Accordingly, the objectives of this study were to verify possible cardiac morphological and functional differences in the left ventricle in patients with or without residual dieresis on chronic hemodialysis treatment.

Patients And Methods

Patients/Protocol

This is a cross-sectional study whose patients were recruited in a private hemodialysis clinic. CKD patients who received regular hemodialysis treatment three times a week and agreed to participate in the study met the inclusion criteria. The exclusion criteria were patients in hemodialysis treatment for less than three months, patients with a previous clinical history of cardiovascular disease, diabetic patients and uncontrolled blood pressure. Using the echocardiogram, those patients with an ejection fraction ≤ 55% and with segmental changes in LV contractility were also excluded [22,23]. Thus, two groups were created: RD+ comprised patients with daily residual diuresis ≥ 100 mL/24 hrs (n = 17; 11♂ and 6♀), and RD- comprised patients with daily residual diuresis < 100 mL/24 hrs (n = 14; 9♂ and 5♀) (Table 1). The following clinical and laboratory data of the groups were assessed: systolic arterial pressure (SAP), diastolic arterial pressure (DAP), length of hemodialysis treatment (LHT), urinary 24-hour volume (UV_{24hs}), hemoglobin (Hb), serum calcium (Ca), parathormone (PTH), serum albumin (Alb) and total peripheral vascular resistance index (TPVRi). This study was previously approved by the Ethics Committee of the Universidade Federal de Uberlândia.

Methods

The SAP and DAP were immediately obtained before the HD session using the arm opposite the AV fistula and represented the average of the last ten HD sessions. Mean arterial blood pressure (MAP) was calculated using the formula DAP + (SAP-DAP/3), and the total peripheral vascular resistance index (TPVRi) was calculated using the formula (MAP-CVP/CD) x 80, where CVP is the central venous pressure, which was always considered a zero value (dyne.seg.cm^{-5}).[24;25] The pressure values were expressed in mmHg. The UV_{24hs} (mL) was collected during the interdialytic period. Interdialytic weight gain (iWG) represents the difference between body weight immediately after the HD session, and the weight obtained immediately before the next HD session. The iWG value was considered the arithmetic average of the last ten HD sessions. The assessment of adequacy of dialysis was done using the Kt/V index. Kt/V is defined as the dialyzer clearance of urea (K, obtained from the manufacturer in mL/min),

Table 1 Clinical characteristics of the patients

	Group RD+ with diuresis	Group RD- without diuresis	p
Clinical Parameters			
Age (years)	48.1 ± 2.6	42.6 ± 3.7	ns
Sex (♂ - ♀)	11/6	9/5	ns
iWG (kg)	2.5 ± 0.16	3.0 ± 0.20	ns
LTH (months)	27.5 ± 3.8	69.0 ± 10.9	0.0006
SAP (mmHg)	121 ± 2.5	118 ± 2.8	ns
DAP (mmHg)	79 ± 1.6	77 ± 2.3	ns
MAP (mmHg)	93 ± 1.7	91 ± 2.2	ns
UV_{24h} (mL/24 h)	849 ± 109	0	< 0.0001
Underlying Diseases			
Chronic glomerulonephritis	11	9	
Hypertension	2	2	
Systemic lupus erythematosus	1	1	
Polycystic kidney disease	1	2	
Congenital malformation - reflux	1	0	
Solitary kidney - atherosclerosis	1	0	
Medication in use			
Diuretics	11	0	
Calcium channel blockers	3	5	
Angiotensin converting enzyme inhibitors	6	3	
β-Adrenergic blockers	7	7	
Drugs by patient	1.7 ± 0.38	1.1 ± 0.27	ns

multiplied by the duration of the dialysis treatment (t, in minutes) divided by the volume of distribution of urea in the body (V, in mL). Biochemical plasma values were obtained using standardized methods that have been previously described.[26-28] The Doppler echocardiogram used the Acuson–Aspen ® C2-4 Mhz transducer conducted in the interdialytic period. The exam was performed twenty hours after finishing the hemodialysis session, in the interdialytic period, by an experienced examiner unaware of the protocol. The Doppler echocardiographic variables were analyzed according to the criteria from the American Society of Echocardiography.[22;29-31] For determination of posterior relative wall thickness (RWT) it was used the measurement of posterior wall thickness (PWT) of the left ventricle.[32-35] The following parameters were also evaluated: the ejection fraction (EF), systolic index (SI), cardiac index (CI), end diastolic volume of the left ventricle (EDV), end diastolic diameter of the left ventricle (EDD), interventricular septum thickness (IVS) and left ventricular mass index (LVMi) [22,24,35]. Additionally, the blood flow of the arteriovenous fistula (BF_{AV}) was assessed with the same echocardiograph equipment.[37;38]

Statistical analysis

For the statistical analysis, we used the GraphPad Prism program, version 5.0, for Windows (GraphPad Software, San Diego California USA). We conducted t-tests and Wilcoxon tests to compare averages between the groups. Values lower than 0.05 were considered significant. The correlation coefficient used was Pearson's correlation coefficient. The data were presented in average ± standard error (X ± SE). A multiple regression test was performed when H0: vascular resistance was not a dependent variable of treatment time and/or residual diuresis and/or PTH and/or mean arterial pressure; while H1: vascular resistance was dependent on at least one of those variables cited above. For these calculations, the Bioestat 5.0 was used and alpha error = 0.05 was considered as a decision level.

Results

Clinical and laboratory characteristics of both groups are presented in Tables 1 and 2.

Table 2 Laboratory, ventricular morphology and hemodynamic parametersa

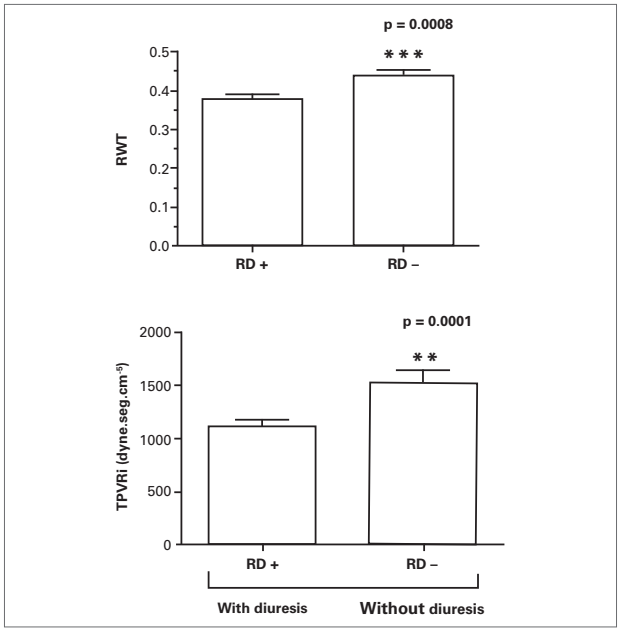
	Group RD+ (17)	Group RD- (14)	p
Laboratory parameters			
Hb (g/dL)	11.6 ± 0.35	11.3 ± 0.45	ns
Ca (mg/dL)	8.9 ± 0.25	8.9 ± 0.24	ns
Alb (g/dL)	3.8 ± 0.05	3.8 ± 0.05	ns
PTH (pg/mL)	277 ± 49.66	508 ± 120.25	ns
Kt/V (mensal)	1.2 ± 0.07	1.4 ± 0.11	ns
Morphological Data of the Left Ventricle			
EDD (mm)	52 ± 0.79	48 ± 1.12	0.0072
IVS (mm)	11.9 ± 0.36	12.9 ± 0.39	ns
PP (mm)	9.9 ± 0.23	10.3 ± 0.32	ns
LVMi (g/m)	132 ± 6.0	130 ± 8.3	ns
RWT	0.38 ± 0.00	0.45 ± 0.01	0.0008
Left Ventricular Function Data			
CI (L/min/m^2)	3.9 ± 0.20	3.0 ± 0.21	0.0056
SI (mL/b/m^2)	54 ± 2.95	45 ± 3.34	0.0403
EVD (mL)	141 ± 6.68	112 ± 7.60	0.0081
CF (bpm)	73 ± 2.97	68 ± 2.61	ns
EF (%)	66 ± 1.14	66 ± 1.46	ns
Hemodynamic Data			
SF_{AV} (L/min)	3.46 ± 0.68	2.26 ± 0.63	ns
TPVRi (dina,seg,cm^{-5})	1121 ± 56	1529 ± 111	0.0017

ns = p > 0.05. Hb: hemoglobin, Ca: calcium, Alb: albumin, PTH: parathyroid hormone, EDD: end diastolic diameter, IVS: intraventricle septum, PWT: posterior wall thickness; LVMi: left ventricular mass index; RWT: relative wall thickness, CI: cardiac index; SI: systolic index, EDV: end diastolic volume; HR: heart rate; EF: ejection fraction; BFAV: fistulae blood flow; TPVRi: total peripheral resistance index.

Morphological data of the left ventricle

The relative wall thickness was significantly lower in group RD+ than in group RD- (0.38 ± 0.01 *vs*. 0.45 ± 0.01; p = 0.0008) (Figure 1). Significant correlations were found between relative wall thickness and: hemodialysis time (r = 0.40; p = 0.024), systolic index (r = - 0.61; p = 0.0003), cardiac index (r = -0.56; p = 0.001) and UV_{24hs} (r = -0.42; p = 0.01). The end diastolic diameter was higher in RD+ (52 ± 0.7 *vs*. 48 ± 1.1; p = 0.0072), and we found significant positive correlations between end diastolic diameter and UV_{24hs} (r = 0.41; p = 0.022) and negative correlations between end diastolic diameter and relative wall thickness (r = -0.60; p = 0.0003).

Figure 1. Relative wall thickness (RWT) and total peripheral vascular resistance index (TPVRi) in RD+ (with diuresis) and RD- (without diuresis) groups.

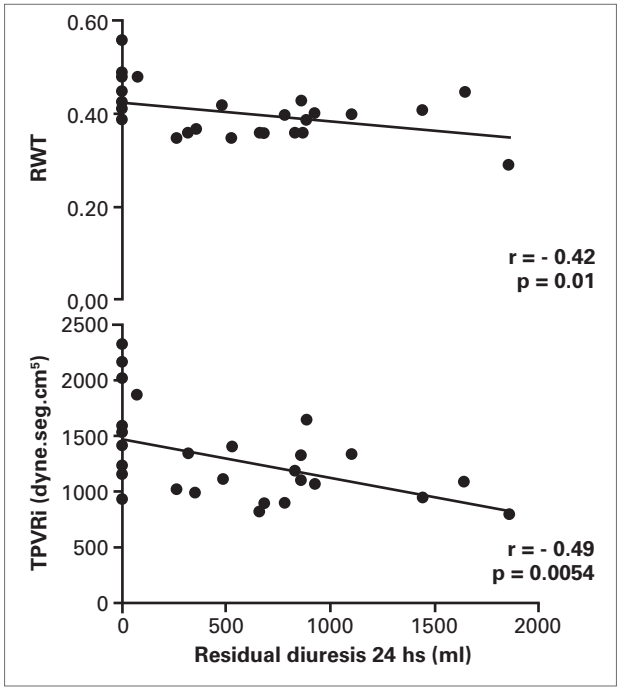


Left Ventricular Function and Hemodynamic Data

The cardiac index of the patients was significantly higher in group RD+ than in group RD- (3.9 ± 0.2 *vs*. 3.0 ± 0.2 L/min/m^2; p = 0.0056). A significant negative correlation between the cardiac index and relative wall thickness was observed (r = - 0.56; p = 0.001). The systolic index was significantly higher in group RD+ (54 ± 2.9 *vs*. 45 ± 3.3 mL/b/m^2; p = 0.0403), as was the end diastolic volume (141 ± 6 *vs*. 112 ± 7 mL; p = 0.0081). The total peripheral resistance index was significantly lower in group RD+ (1121 ± 56 *vs*. 1529 ± 111 dina.seg.cm^{-5}; p = 0.001) (Figure 1, Table 1). The BF_{AV} was not statistically different between groups RD+ and RD- (1.8 ± 0.6 *vs*. 1.4 ± 0.6 L/min/m^2; p = ns).

It was observed a significant positive correlation between the systolic index and left ventricular mass index (r = 0.51; p = 0.0039), between the total peripheral resistance index and relative wall thickness (r = 0.51; p = 0.0036) and systolic index and relative wall thickness (r = - 0.61; p = 0.0003). The TPVRi correlated with the CI, SI, RWT and UV_{24h} (Figures 2 and 3) (Table 2). For the multiple regression analysis the TPVRi was considered as a dependent variable while time of treatment, residual diuresis, PTH and MAP were considered as variables that could influence the peripheral resistance index. We found that F regression = 4.26, p = 0.041, rejected H0 and the following partial coefficients: time (t: -1.47; p = 0.152); residual diuresis (t: -3.35; p = 0.0023); MAP (t: 0.490; p = 0.490) and PTH (t: = 0.498 p = 0.6225).

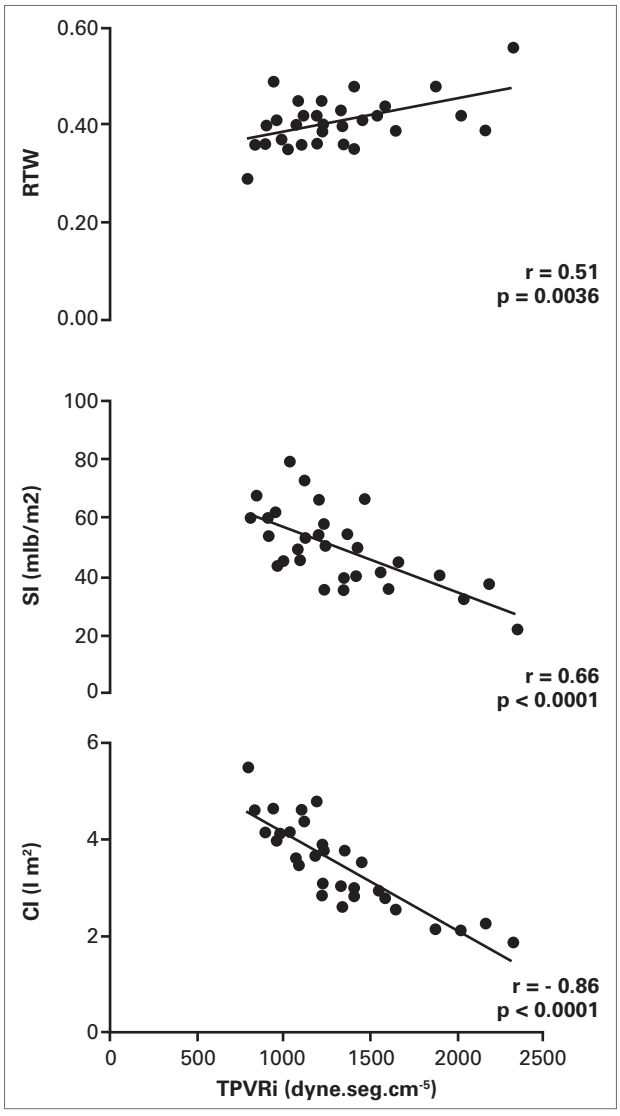
Figure 2. Residual diuresis (RD), total peripheral vascular resistance index (TPVRi) and relative wall thickness (RWT) correlations.



Discussion

Relative wall thickness constitutes one of the variables used to define the geometric pattern of the left ventricle.[22;32;39] Thus, in our study, we observed that the patients in groups RD+ and RD- had similar left ventricular masses and different values of relative wall thickness (Table 2). This data suggested that both groups would have distinct ventricular morphologies and the load resistance and volume imposed on the left ventricle would be of different magnitudes. This fact becomes more evident, as we found a correlation between peripheral resistance and relative

Figure 3. Total peripheral vascular resistance index (TPVR), cardiac index (CI), systolic index (SI) and relative wall thickness (RWT) correlations.



wall thickness, suggesting that, for different values of resistance, there are different values of thickness on the posterior wall (Figure 2). The absence of residual diuresis may have contributed to higher peripheral resistance values and hypervolemic status in the anuric group. Although the interdialytic weight gain was not significant between the groups due to the small size of this sample, the group without diuresis were about 20 per cent heavier than the group with urinary volume. Our data also showed that low-volume diuresis coexisted with high values of peripheral resistance (Figure 2). Wang *et al*. found that left ventricular mass increased in peritoneal dialysis patients who had lower glomerular filtration rates.[9] However, these authors found similar end diastolic diameters among the assessed groups, which differs from the findings in our study. One of the possible reasons for these different findings could be due to the type of dialysis, while another reason may be that the authors did not correlate modifications in the left ventricle with the residual 24-hour urinary volume of their patients.

With respect to the functional characteristics of the left ventricle, we observed that CI and SI were lower in the anuric patients (RD-) (Table 2). This finding could be explained by the lower values found in the end ventricular diastolic diameter in RD- (Table 2). The morphological differences of left ventricles between the two groups were responsible for distinct values of cardiac and systolic indexes. Therefore, CKD patients on hemodialysis treatment who lose residual diuresis may have changes in the geometry and function of the left ventricle.

Although Faguli *et al*. demonstrated LVH in the majority of the hemodialyzed patients studied, these authors did not exclude patients with pathologies that could interfere with the myocardium remodeling process, such as diabetes mellitus, ischemic cardiomyopathy or systemic arterial hypertension; further, they did not correlate their findings with the residual urinary volume.[40]

In CKD patients, RD progressively decreased with time in replacement therapy. In our study, the anuric group (RD-) spent more time in HD treatment than the group with dieresis (RD+), and the loss of urinary volume only happened in patients with the largest length time on treatment. The reasons for losing the residual diuresis may be explained by the changes related to the underlying disease that caused the CKD or by a continuous inflammatory process, anemia and associated co-morbidities.[12,17,41-43] The length of time spent on hemodialysis could increase the potential risks to the left ventricle. These risks come from the treatment itself and from the progression of the illness. However, applying multiple regression and defining the load imposed on the left ventricle as a dependent variable we found a statistical significance only for residual diuresis ($p = 0.05$). The length of time spent on dialysis therapy, PTH and mean arterial pressure did not have significant values. These data were more relevant because patients were normotensive, thus the volume component of blood pressure could be greater than the resistive component in these patients.

In this study, the morpho-functional cardiac changes could not be attributed to the blood pressure levels found, because the groups RD+ and RD- demonstrated similar diastolic and systolic blood pressure values (Table 1). The same could be said with regard to the use of anti-hypertensive drugs, as there

was no difference in the number of hypertensive medications used in both groups (Table 1). Gunal *et al*. demonstrated that the use of anti-hypertensive drugs contributed to LVMi reductions in only 6% of the patients on hemodialysis (11). However, our results demonstrated that both groups RD+ and RD- did not show differences in their LVMi values ($p > 0.05$) (Table 2), indicating that the effect of the drugs used did not substantially interfere with our results.

The presence of anemia is another factor that could be related to the presence of LVH.[44;45] The role of anemia as a cause of LVH in patients undergoing dialysis has been well established; correction of anemia with erythropoietin results in the partial regression of LVH (46). In this study, the Hb level remained relatively normal, and there was no difference in Hb level between the groups studied (Table 2).

It has already been shown that hypoalbuminemia is involved in ventricular hypertrophy and dilatation, and in heart failure, and, ultimately decreases patients' survival.[47-51] The CANUSA study demonstrated that serum Alb concentration strongly correlated with mortality.[3,52] In our study, the serum Alb values were normal; we did not find significant differences between the two groups (Table 2). Therefore, we believe that the cardiac changes found in our study could not have been caused by this variable. Persistent hypocalcemia is considered a pathogenic factor in the reduction of left ventricular systolic function.[53] However, serum calcium in our study remained at normal values; there was no difference between the two groups (Table 2). Secondary hyperparathyroidism is common in uremic patients, and this complication has contributed to the development of left ventricular systolic dysfunction[54] and LVH.[55] PTH serum levels between the groups were statistically non significant (Table 2). The BF_{AV} is another important factor that contributes to cardiac morphology and function.[38;56] In our study, all fistulas were examined by using their blood flows; there was no statistically significant difference between the groups (Table 2). In addition, morphological and functional changes may be attributed to the different removal rates of solutes in the hemodialysis process; however, they were not different in RD+ and RD-. It is worth noting that the Kt/V measurement in our study did not take into account solute removals promoted by residual diuresis (Table 2).

Based on our study findings, we conclude that the different CI and SI values found in these groups can be attributed to distinct ventricular geometric patterns that are determined by total peripheral resistance and by the presence of residual diuresis. Therefore, the preservation of diuresis appears to influence left ventricular morphology and function in patients with chronic kidney failure.

As limitations of this study it is necessary to observe that it is a cross sectional study and the data of the patients represent the moment when the variables were observed, and they could not express the exactly progression of the patient disease. Beside this, the small size of samples could induce an alpha error in its statistics analyses.

We believe that more prospective studies should be conducted in order to confirm such a hypothesis.

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