Long-term impacts of different dialysis modalities on right ventricular function in patients with end-stage renal disease

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Abstract

Background Right ventricular dysfunction is a major cause of heart failure and mortality in end-stage renal disease patients. Scarce data is available regarding the comparison of echocardiographic right ventricular function in end-stage renal disease patients on hemodialysis (HD) and peritoneal dialysis (PD). The aim of the study was to evaluate the long-term impacts of different dialysis modalities on right ventricular function assessed by conventional echocardiography, in end-stage renal disease patients with preserved left ventricular function. *Methods* The study included 120 patients grouped as follows: PD(n=40), HD with arterio-venous fistula (n=40) and healthy control subjects (n=40). Conventional echocardiography was performed in all patients. A classification of right ventricular function was defined in HD patients by using tricuspid annular plane systolic excursion (TAPSE), right ventricular myocardial performance index (RV-MPI), fractional area change (FAC) and tricuspid lateral annulus systolic velocity (Sa) values. Correlation analysis was performed by using right ventricular dysfunction score, clinical and echocardiographic parameters. *Results* The mean age of the study population was 51.9±13.1 years and 47.5% were females. TAPSE and Sa velocity were found to be significantly lower and RV-MPI was significantly higher in patients undergoing HD, compared with control and PD patients. Logistic regression analysis showed that HD treatment was an independent risk factor for developing right ventricular dysfunction. *Conclusion* RV function was impaired in patients undergoing HD compared with patients on PD.

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ORIGINAL ARTICLE

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Long-term impacts of different dialysis modalities on right ventricular function in patients with end-stage renal disease: A cross-sectional, observational study

ABSTRACT

Background

Right ventricular dysfunction is a major cause of heart failure and mortality in end-stage renal disease patients. Scarce data is available regarding the comparison of echocardiographic right ventricular function in end-stage renal disease patients on hemodialysis (HD) and peritoneal dialysis (PD). The aim of the study was to evaluate the long-term impacts of different dialysis modalities on right ventricular function assessed by conventional echocardiography, in end-stage renal disease patients with preserved left ventricular function.

Methods

The study included 120 patients grouped as follows: PD(n=40), HD with arterio-venous fistula (n=40) and healthy control subjects (n=40). Conventional echocardiography was performed in all patients. A classification of right ventricular function was defined in HD patients by using tricuspid annular plane systolic excursion (TAPSE), right ventricular myocardial performance index (RV-MPI), fractional area change (FAC) and tricuspid lateral annulus systolic velocity (Sa) values. Correlation analysis was performed by using right ventricular dysfunction score, clinical and echocardiographic parameters.

Results

The mean age of the study population was 51.9±13.1 years and 47.5% were females. TAPSE and Sa velocity were found to be significantly lower and RV-MPI was significantly higher in patients undergoing HD, compared with control and PD patients. Logistic regression analysis showed that HD treatment was an independent risk factor for developing right ventricular dysfunction.

Conclusion

RV function was impaired in patients undergoing HD compared with patients on PD.

Key words : echocardiography, end stage renal disease, hemodialysis, peritoneal dialysis, right ventricular function

Author key words: dialysis, conventional echocardiography, heart failure, right ventricular dysfunction

Clinical trials registration number: NCT04524468

Long-term impacts of different dialysis modalities on right ventricular function in patients with end-stage renal disease

INTRODUCTION

There has been a rise in the incidence and prevalence of end-stage renal disease (ESRD) in recent years. [1] Cardiovascular diseases (CVD) are the main causes of death in patients undergoing dialysis. [2] The role of the traditional risk factors (e.g., arterial hypertension, diabetes mellitus) is important in the pathogenesis of CVD, however it can not be fully explained with these risk factors. [3]

Right ventricular (RV) dysfunction is one of the major predictors of mortality and heart failure in this patient group. It has been shown that patients undergoing hemodialysis (HD), which is usually carried out via a surgically created arteriovenous fistula (AVF), have an increased risk for pulmonary hypertension and poorer right ventricular function compared with healthy controls. [4,5] Chronic pressure/volume overload of the RV determined by AVF leads to a progressive rise in pulmonary pressures and deteriorates RV function.[6] However, several other pathogenic mechanisms and risk factors which are frequently observed in ESRD patients, can be responsible for RV dysfunction.

In our previous study that we compared peritoneal dialysis (PD) patients and healthy controls in terms of echocardiographic RV function, we showed that RV function, assessed by conventional echocardiography in PD patients, did not differ from healthy controls. [7]However, the literature includes a limited number of studies regarding the comparison of the effects of different dialysis modalities on RV function in ESRD patients. The aim of the current study was to elucidate the impact of both long-term PD and HD therapy via AVF, on RV function in ESRD patients with preserved left ventricular (LV) function.

METHODS

The current study was planned as a cross-sectional observational study that included eighty ESRD patients >18 years on a regular dialysis program for at least six months, and forty healthy subjects. Patients were recruited from the dialysis unit of the XXXX Hospital, between January 2020 and June 2020. Those undergoing dialysis were grouped as follows: forty patients on PD and forty patients on HD with AVF. Patients undergoing HD were receiving standard bicarbonate HD sessions three times per week, lasting four hours. Every participant provided informed consent. The study was conducted in accordance with the Declaration of Helsinki and approved by the local Ethics Committee (2019-398).

Clinical or echocardiographic evidence of ischemic heart disease, left ventricular systolic dysfunction with an ejection fraction (EF) of less than 55%, valvulopathy, left bundle branch block, atrial fibrillation, previous renal transplantation were accepted as exclusion criteria. Any clinical condition that might predispose the patient to pulmonary hypertension (chronic obstructive pulmonary disease, interstitial lung diseases, connective tissue disorders, chronic thromboembolic disease, congenital left-to-right shunt, primary pulmonary hypertension), was also a criterion for exclusion.

All of the patients were subjected to a comprehensive clinical evaluation. Blood pressure (BP) was measured after at least 10-minutes rest in a sitting position. The mean of three measurements of each patient was recorded. Patients were defined as having hypertension (HT) if their SBP was >140 mmHg, their DBP was >90 mmHg, or they were using an antihypertensive medication.[8] Diabetes was defined by treatment with anti-diabetic medications. Body mass index (BMI) was calculated as body weight divided by height squared (kg/m^2). Body surface area (BSA; in m^2) was calculated as 0.0061 x height (cm) + 0.0124 x weight (kg) – 0.0099.

Echocardiography

All of the study patients underwent transthoracic echocardiography. Images were obtained via a Philips iE33 machine (Philips Medical Systems, Andover, USA) with a 3,5 MHz transducer with the patient in the left lateral decubitus position, by a single experienced cardiologist who was blinded to the clinical data of the

patients. Echocardiograms were performed within 1 hour after HD while patients were at optimal dry weight for patients on HD and at empty abdomen for patients undergoing PD. Electrocardiogram and respiration of the patients were recorded. Echocardiographic images with at least 3 cardiac cycles were recorded at the end of expiration. Measurements were obtained according to the recommendations of American Association of Echocardiography and European Association of Cardiovascular Imaging. [9]

The left ventricular end-diastolic diameter (LVDD), left ventricular end-systolic diameter (LVESD), interventricular septum thickness (IVST), posterior wall thickness (PWT) and left ventricular outflow tract (LVOT) diameter were measured in the parasternal long axis view. Left ventricular mass (LVM) was estimated using the anatomically validated formula of Devereux et al. [10] Left ventricular ejection fraction (LVEF) was calculated using Simpson's biplane method. Left atrial (LA) diameters were measured from the parasternal long axis and apical 4-chamber views. LAV was calculated using the biplane Simpson method. LVM and LAV were adjusted to body surface area (BSA), as were the LVM index (LVMI) and LAV index (LAVI). To evaluate the diastolic function of LV, early mitral inflow velocity (E), late mitral inflow velocity (A) and E/A ratio were recorded. Early diastolic velocity of the lateral mitral annulus (Em) was recorded with tissue Doppler imaging (TDI) and the E/Em ratio was also evaluated.

Right heart diameters were measured from the apical 4-chamber views focused on RV and RA. Maximal tricuspid regurgitation velocity was measured using continuous wave Doppler echocardiography in the apical 4-chamber view. Pulmonary artery systolic pressure (PASP) was calculated as follows: 4 x (tricuspid systolic jet)^2 + right atrial pressure, as assessed by the inspiratory collapse of the inferior vena cava. Early (E) and late (A) RV inflow velocities were measured with pulsed wave Doppler by placing the sample volume between the tips of the tricuspid valve in the apical 4-chamber view. Pulsed wave TDI was obtained in the apical 4-chamber view by placing a 5 mm to 10 mm sample volume at the lateral side of the tricuspid annulus. Measurements were recorded during end-expiratory apnea. On the TDI images, peak annular systolic velocity (Sa), early diastolic (Ea) and late diastolic (Aa) annular velocities were measured. Ejection time (ET) was measured from right ventricular outflow tract pulse Doppler and tricuspid valve closure and opening time (TCO) was measured from the tricuspid inflow pulse Doppler. The pulsed Doppler derived MPI, as a global estimate of both systolic and diastolic functions of RV, was calculated with the formula RV-MPI = (TCO-ET) / ET. Tricuspid annular plane systolic excursion (TAPSE) was calculated by placing an M-mode cursor through the tricuspid annulus and measuring the longitudinal motion of the annulus at peak systole in the apical 4-chamber view. Fractional area change (FAC) was obtained by tracing the RV endocardium both in end-systole and end-diastole from the annulus, along with the free wall to the apex, and then back to the annulus with the interventricular septum in the apical 4-chamber view focused on RV. RV FAC was calculated using the formula FAC = (end-diastolic area – end-systolic area) / end-diastolic area x 100. All these measurements and calculations were performed according to guidelines for the Echocardiographic Assessment of the Right Heart in Adults.[11]

We defined a classification indicating RV function of patients by using TAPSE, RV-MPI, FAC and tricuspid lateral annulus Sa velocity values. Patients who had normal values in all these parameters, according to the universally accepted values defined in the guidelines, were considered to have zero point. Those having an abnormality in one of these parameters were assigned one point, two abnormal parameters received two points and three abnormal parameters were assigned three points. Patients with zero point were accepted as having normal RV function, whereas patients with at least one point were accepted as having abnormal RV function.

Sample Calculation

The total sample size of 120 subjects achieves 91% power to detect differences among the means versus the alternative of equal means using an F test with a 0.05 significance lelvel. The size of the variation in the means is represented by 0.35 effect size. The common standart deviation within a group is assumed to be 3.0.

Statistical Analysis

Continuous variables were reported as mean ± standard deviation, whereas categorical variables were expressed as percentage values. Normal distribution of the data was tested using the Kolmogorov-Smirnov test and categorical variables were compared using the chi-square test. Comparisons of normally distributed continuous variables were performed with the Student's t-test and the Mann Whitney-U test was used for non-parametric continuous variables. Analysis of variance (ANOVA) followed by the Tukey correction was used to assess difference among 3 groups. The correlation between variables was examined by Pearson's correlation coefficient. Multiple logistic regression analyses were performed to define risk factors of outcome variable. All potentially relevant confounding factors were considered all together in the model. Intraobserver variability of echocardiographic RV functional measurements was assessed using intraclass correlation coefficients and coefficients of variation. P value <0.05 was considered statistically significant. Statistical analyses were performed using the Statistical Package for the Social Sciences statistical software (version 25; SPSS-IBM, Chicago, IL, USA).

RESULTS

The study population consisted of 120 patients grouped as follows: patients undergoing PD (n=40), patients undergoing HD with AVF (n=40) and healthy control group patients (n=40). The mean age of the study population was 51.9±13.1 years and there were 57 females (47.5 %). Groups did not show significant difference in regards to age, gender, smoking status, diastolic blood pressure and heart rate. No significant difference was found in dialysis duration among both dialysis groups. The prevalence of diabetes was similar among all groups, whereas hypertension prevalence was higher in end-stage renal disease patients compared to healthy controls. While BMI values did not differ between control and PD groups, it was significantly lower in patients on HD. General characteristics of the study population were demonstrated in Table 1.

Echocardiographic Left Atrial and Left Ventricular Indices

LVMI, LVOT diameter and LAVI were significantly higher in dialysis patients than in controls. Mitral A velocity was significantly lower in patients on dialysis compared to control patients. No significant differences in LVEF, E/A and E/Em values were found among the groups (Table 2).

Echocardiographic Right Atrial and Right Ventricular 2-D and M-Mod Indices

Patients on HD presented significantly lower TAPSE values compared to PD patients and controls (17.99 ± 3.91, 22.60 ± 4.75 and 25.57 ± 4.33 mm, respectively; $p<0.001$). We found no significant difference in right atrial diameters and FAC values among dialysis groups. Right ventricular basal diameters were significantly higher in HD patients compared to controls (Table 3).

Echocardiographic Right Ventricular Doppler Indices

Sa velocity, as an index of right ventricular systolic function, was reduced significantly among HD patients compared to PD and control groups. RV MPI s and PASP values were increased significantly in HD patients compared to patients on PD and controls (Table 4).

For the reliability of the TAPSE and Sa average measurement, the interclass correlation coefficient for the intraobserver variability were 0.963 [95% confidence interval (CI) 0.925-0.980; $P<0.001$] and 0.940 [95% confidence interval (CI) 0.917-0.957; $P<0.001$] respectively.

According to the examination of the RV dysfunction scores; while 30 patients in HD group had at least 1 point; 11 patients in PD group and 9 patients in control group had 1 point (Table 1).

Regarding the correlation analysis, RV dysfunction score of HD patients had weak correlations with LVOT diameter, Em and E\Em, among left heart echocardiographic parameters. Among clinical parameters, there was also a weak correlation between RV dysfunction score and the age of the patients. The RV dysfunction score also had statistically significant correlations with Ea velocity, Aa velocity and E\Ea, among right heart echocardiographic parameters (Table 5).

Logistic regression analysis adjusted for age and right Aa velocity showed that HD treatment was an independent risk factor for developing RV dysfunction. (Table 6).

DISCUSSION

In the present study, we investigated the impact of different dialysis modalities on echocardiographic RV function in ESRD patients with preserved left ventricular function. We demonstrated that patients on HD with AVF have poorer RV function compared with the patients undergoing PD and HD treatment is an independent risk factor for developing RV dysfunction.

Heart failure is associated with significant morbidity and mortality in ESRD patients on dialysis, however it remains poorly investigated. RV dysfunction has been reported as a significant indicator of mortality in heart failure patients, regardless of left ventricular systolic dysfunction and valvular disease. [12] A survival analysis including echocardiographic parameters reported that RV dysfunction is significantly associated with impaired survival in ESRD patients. [13] There is data suggesting that RV dysfunction is more common in patients on HD. [14]Several pathophysiological mechanisms may be responsible for the deterioration of RV function: sympathetic activation, anemia, secondary hyperparathyroidism, inflammation and left-to-right shunt caused by AVF.[15]AVF leads to chronic volume overload, causing left to right shunt. Data from several studies suggest that mortality and heart failure prevalence may be increased in AVF patients.[16,17] In a study by Reddy et al., it was reported that AVF creation for the initiation of HD in patients with ESRD, is associated with modest impairment in LV function and remodeling in the RV. [18] Another study using strain echocardiography, demonstrated that patients with ESRD and preserved LV EF undergoing HD have higher prevalence of LV diastolic dysfunction and reduced RV longitudinal function and deformation parameters, compared with healthy controls. [19] Sun et al. suggested that patients on HD endure the deterioration of RV function and demonstrated RV morphological and dysfunction, compared with control group.[20] Karavelioglu et al. also stated that RV functions were deteriorated in ESRD patients on HD compared to healthy subjects.[21]

There is, however, a lack of data on the impact of different dialysis modalities on RV function. In the present study, we compared the long-term impacts of PD and HD with AVF on RV function in ESRD patients with preserved LV systolic function and demonstrated the deterioration of RV function in HD patients, compared with the patients on PD. TAPSE and tricuspid lateral annulus Sa values, which reflect the systolic function of RV, were found to decrease; additionally, RV MPI, an indicator of global RV function, was found to increase in patients on HD compared with PD patients. Logistic regression analysis demonstrated HD treatment as an independent predictor of RV dysfunction and also Ea velocity of tricuspid lateral annulus, as associated with RV dysfunction. Our results were consistent with a previous, similar study by Paneni et al., that investigated RV function in different dialysis modalities. They demonstrated a higher prevalence of RV dysfunction among HD patients when compared to patients on PD and also noted that RV dysfunction was more prevalent in brachial AVF patients, compared to the patients with radial AVF. [22] Different from Paneni's study that evaluated RV MPI and tricuspid lateral annulus Sa velocities, we also investigated TAPSE and RV FAC, and defined a classification score, indicating RV function of the patients, by using these four echocardiographic parameters. The results of the present study emphasize the deterioration of RV function in patients undergoing HD, regardless of LV function and PASP, compared with the subjects on PD; this suggests the deterioration of RV independent of LV dysfunction and pulmonary hypertension.

Considering the vital role of RV dysfunction in the development of heart failure in ESRD patients, the choice of dialysis treatment modality is of great importance for patients at high risk for heart failure. Additionally, close follow-up of HD patients for RV function is necessary for detection, prevention and early treatment of heart failure in this patient group.

The lack of gold standards, such as magnetic resonance imaging or strain echocardiography for the assessment of RV and LV function is the main limitation of the present study. However, despite the difficulties in the evaluation of RV due to its complex anatomy and retrosternal position, transthoracic echocardiography is an accurate, easy, rapid, reproducible and noninvasive method to assess RV function. Further larger scale studies are needed to confirm these results and also evaluate the clinical importance and prognostic value of

the results.

In conclusion, this study has demonstrated that RV function assessed by echocardiography was poorer in patients undergoing HD with AVF compared to the patients on PD, regardless of LV function and pulmonary hypertension. Accordingly, HD patients should be evaluated frequently for the development of RV dysfunction. The echocardiographic parameters reflecting RV function, should be examined and reported in patients on HD.

REFERENCES

1. Gonzalez-Bedat M, Rosa-Diez G, Pecoits-Filho R, et al.Burden of disease: prevalence and incidence of ESRD in Latin America. Clin Nephrol. 2015; 83:3-6.
2. Mavrakanas TA, Charytan DM. Cardiovascular complications in chronic dialysis patients. Curr Opin Nephrol Hypertens. 2016; 25:536-544.
3. Foley RN, Parfrey PS, Sarnak MJ. Epidemiology of cardiovascular disease in chronic renal disease. J Am Soc Nephrol. 1998; 9:16-23.
4. Yigla M, Banderski R, Azzam ZS, Reisner SA, Nakhoul F. Arterio-venous access in end-stage renal disease patients and pulmonary hypertension. Ther Adv Respir Dis. 2008; 2:49-53.
5. Momtaz M, Fishawy HA, Aljarhi UM, et al. Right ventricular dysfunction in patients with end-stage renal disease on regular hemodialysis. The Egyptian Journal of Internal Medicine. 2013; 25:127-132.
6. Paneni F, Gregori M, Ciavarella GM, et al. Relation between right and left ventricular function in patients undergoing chronic dialysis. J Cardiovasc Med (Hagerstown). 2013; 14:289-295
7. Demirci DE, Demirci D, Çoban M, Öztekin GMY, Arslan Ş. Echocardiographic assessment of right ventricular function in peritoneal dialysis patients. Turk Kardiyol Dern Ars. 2019; 47:88-94.
8. Mancia G, Fagard R, Narkiewicz K, et al. (2013) 2013 ESH/ESC guidelines for the management of arterial hypertension: the task force for the management of arterial hypertension of the European society of hypertension (ESH) and of the European society of cardiology (ESC). Eur Heart J 34:2159-2219.
9. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American society of echocardiography and the European association of cardiovascular imaging. J Am Soc Echocardiogr. 2015; 28:1-39.
10. Devereux RB, Alonso DR, Lutas EM, et al. Echocardiographic assessment of left ventricular hypertrophy: comparison to necropsy findings.*Am J Cardiol.* 1986;57:450-458.
11. Rudski LG, Lai WW, Afilalo J, et al. Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography. J Am Soc Echocardiogr. 2010; 23:685-713.
12. Kjaergaard J, Akkan D, Iversen KK, et al. Right ventricular dysfunction as an independent predictor of short- and long-term mortality in patients with heart failure. Eur J Heart Fail. 2007; 9:610-616.
13. Stallworthy EJ, Pilmore HL, Webster MW, et al. Do echocardiographic parameters predict mortality in patients with end-stage renal disease? Transplantation. 2013; 95:1225-1232.
14. Beigi AA, Sadeghi AM, Khosravi AR, Karami M, Masoudpour H. Effects of the arteriovenous fistula on pulmonary artery pressure and cardiac output in patients with chronic renal failure. J Vasc Access. 2009; 10:160-166.
15. Peng W , Li Z, Xu H, et al. Assessment of right ventricular dysfunction in end-stage renal disease patients on maintenance haemodialysis by cardiac magnetic resonance imaging. Eur J Radiol. 2018;102:89-94.
16. van de Luijtgaarden MW, Jager KJ, Segelmark M, et al. Trends in dialysis modality choice and related patient survival in the ERA-EDTA Registry over a 20-year period. Nephrol Dial Transplant. 2016;31:120-128.
17. Rao NN, Dundon BK, Worthley MI, Faull RJ.The impact of arteriovenous fistulae for hemodialysis on the cardiovascular system. Semin Dial. 2016; 29:214-221.

18. Reddy YNV, Obokata M, Dean PG, et al. Long term cardiovascular changes following creation of arteriovenous fistula in patients with end stage renal disease. Eur Heart J. 2017; 38:1913-1923.
19. Tamulėnaitė E, Žvirblytė R, Ereminienė R, et al. Changes of Left and Right Ventricle Mechanics and Function in Patients with End-Stage Renal Disease Undergoing Haemodialysis. Medicina (Kaunas). 2018; 54:87.
20. Sun M, Cao X, Guo Y, et al. Long-term impacts of hemodialysis on the right ventricle: Assessment via 3-dimensional speckle-tracking echocardiography. Clin Cardiol. 2018; 41:87-95.
21. Karavelioğlu Y, Özkurt S, Kalçik M, Karapinar H, Arisoy A. Echocardiographic assessment of right ventricular functions in nondiabetic normotensive hemodialysis patients. Interv Med Appl Sci. 2015; 7:95-101.
22. Paneni F, Gregori M, Ciavarella GM, et al. Right Ventricular Dysfunction in Patients with End-Stage Renal Disease. Am J Nephrol. 2010; 32:432-438.

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Table 1. General Characteristics of the study population	Table 1. General Characteristics of the study population	Table 1. General Characteristics of the study population	Table 1. General Characteristics of the study population	Table 1. General Characteristics of the study population
	Controls (n=40)	**PD (n=40)**	**HD (n= 40)**	**p value**
Age, years	51.2 ± 11.4	52.4 ± 12.9	52.9 ± 15.6	0.836
Female gender, n (%)	25 (63)	16 (40)	16 (40)	0.072
Hypertension, n (%)	13 (32.5)	32 (80.0) *	23 (57.5) *	**<0.001**
Diabetes, n (%)	9 (22.5)	13 (32.5)	9 (22.5)	0.156
Current smoking, n (%)	10 (25.0)	7 (17.5)	10 (25.0)	0.853
Body mass index (kg/m^2)	29.10 ± 5.12	27.96 ± 5.57	23.97 ± 4.33§	**<0.001**
Systolic BP (mmHg)	119.0 ± 15.65	135.17 ±23.87*	128.2 ± 22.56	**0.004**
Diastolic BP (mmHg)	75.52 ± 9.76	79.05 ±14.89	77.45 ± 12.60	0.226
Heart rate (beats/min) median /Q1/Q3	76 /72/84	77/68/86	77/69/82	0.800
RV dysfunction score				
0	31 (77.5)	26 (65)	10 (25.0)	
1	9 (22.5)	11 (27.5)	13 (32.5)	
2	0	0	11 (27.5)	
3	0	0	5 (12.5)	
4	0	0	1 (2.5)	
Dialysis vintage (months) median /Q1/Q3	———	36/13/58	36/13/81	0.447

Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. *different from control, p < 0.001 and p=0.003, respectively for HT, p= 0.002 for systolic BP § different from control and peritoneal dialysis p <0.001 for body mass index BP: blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RV: right ventricle	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. *different from control, p < 0.001 and p=0.003, respectively for HT, p= 0.002 for systolic BP § different from control and peritoneal dialysis p <0.001 for body mass index BP: blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RV: right ventricle	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. *different from control, p < 0.001 and p=0.003, respectively for HT, p= 0.002 for systolic BP § different from control and peritoneal dialysis p <0.001 for body mass index BP: blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RV: right ventricle	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. *different from control, p < 0.001 and p=0.003, respectively for HT, p= 0.002 for systolic BP § different from control and peritoneal dialysis p <0.001 for body mass index BP: blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RV: right ventricle	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. *different from control, p < 0.001 and p=0.003, respectively for HT, p= 0.002 for systolic BP § different from control and peritoneal dialysis p <0.001 for body mass index BP: blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RV: right ventricle

Table 2. Left ventricular echocardiographic parameters	Table 2. Left ventricular echocardiographic parameters	Table 2. Left ventricular echocardiographic parameters	Table 2. Left ventricular echocardiographic parameters	Table 2. Left ventricular echocardiographic parameters
	Controls (n:40)	**PD (n=40)**	**HD (n= 40)**	**p value**
LVEDD (mm)	45.15 ± 4.17	46.45 ± 5.26	43.84 ± 6.36	0.097
LVESD (mm)	27.90 ± 5.35	30.12 ± 5.79	29.74 ± 4.98	0.102
LVMI (g/m^2)	94.62 ± 31.39	115.38 ± 37.88	125.26 ± 56.61*	**0.007**
LAVI (mL/m^2)	17.44 ± 4.27	22.92 ± 5.88*	22.01 ± 7.04*	**<0.001**
LVOT (mm)	21.04 ± 2.88	22.45 ± 3.40	23.90 ± 3.22*	**<0.001**
E (m/s)	78.00 ± 17.19	69.82 ± 17.50	80.98 ± 25.08	0.045
A (m/s)	72.17 ± 23.75	90.37 ± 20.59*	88.50 ± 23.21*	**0.001**
Em (m/s)	9.33 ± 2.64	7.72 ± 3.02	8.04 ± 3.70	0.073
E/A	1.18 ± 0.42	0.92 ± 1.04	0.97 ± 0.43	0.223
E/Em	9.11 ± 3.40	10.43 ± 5.51	11.80 ± 5.89	0.063
LVEF (%)	62.47 ± 2.84	62.25 ± 5.18	61.12 ± 2.65	0.229

Data is presented as mean $\pm$ standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, $p<0.006$ for LVMI; $P<0.001$ and $p=0.002$, respectively for LAVI; $P<0.001$ for LVOT; $P=0.001$ and $p=0.005$, respectively for A velocity A: Late mitral inflow velocity, E: Early mitral inflow velocity, Em: Early diastolic velocity of mitral annulus, HD: hemodialysis, LVEDD: Left ventricular end-diastolic diameter, LVESD: Left ventricular end-systolic diameter, LVMI: Left ventricular mass index, LAVI: Left atrial volume index, LVOT: Left ventricular outflow tract, LVEF: Left ventricular ejection fraction, PD: peritoneal dialysis	Data is presented as mean $\pm$ standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, $p<0.006$ for LVMI; $P<0.001$ and $p=0.002$, respectively for LAVI; $P<0.001$ for LVOT; $P=0.001$ and $p=0.005$, respectively for A velocity A: Late mitral inflow velocity, E: Early mitral inflow velocity, Em: Early diastolic velocity of mitral annulus, HD: hemodialysis, LVEDD: Left ventricular end-diastolic diameter, LVESD: Left ventricular end-systolic diameter, LVMI: Left ventricular mass index, LAVI: Left atrial volume index, LVOT: Left ventricular outflow tract, LVEF: Left ventricular ejection fraction, PD: peritoneal dialysis	Data is presented as mean $\pm$ standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, $p<0.006$ for LVMI; $P<0.001$ and $p=0.002$, respectively for LAVI; $P<0.001$ for LVOT; $P=0.001$ and $p=0.005$, respectively for A velocity A: Late mitral inflow velocity, E: Early mitral inflow velocity, Em: Early diastolic velocity of mitral annulus, HD: hemodialysis, LVEDD: Left ventricular end-diastolic diameter, LVESD: Left ventricular end-systolic diameter, LVMI: Left ventricular mass index, LAVI: Left atrial volume index, LVOT: Left ventricular outflow tract, LVEF: Left ventricular ejection fraction, PD: peritoneal dialysis	Data is presented as mean $\pm$ standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, $p<0.006$ for LVMI; $P<0.001$ and $p=0.002$, respectively for LAVI; $P<0.001$ for LVOT; $P=0.001$ and $p=0.005$, respectively for A velocity A: Late mitral inflow velocity, E: Early mitral inflow velocity, Em: Early diastolic velocity of mitral annulus, HD: hemodialysis, LVEDD: Left ventricular end-diastolic diameter, LVESD: Left ventricular end-systolic diameter, LVMI: Left ventricular mass index, LAVI: Left atrial volume index, LVOT: Left ventricular outflow tract, LVEF: Left ventricular ejection fraction, PD: peritoneal dialysis	Data is presented as mean $\pm$ standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, $p<0.006$ for LVMI; $P<0.001$ and $p=0.002$, respectively for LAVI; $P<0.001$ for LVOT; $P=0.001$ and $p=0.005$, respectively for A velocity A: Late mitral inflow velocity, E: Early mitral inflow velocity, Em: Early diastolic velocity of mitral annulus, HD: hemodialysis, LVEDD: Left ventricular end-diastolic diameter, LVESD: Left ventricular end-systolic diameter, LVMI: Left ventricular mass index, LAVI: Left atrial volume index, LVOT: Left ventricular outflow tract, LVEF: Left ventricular ejection fraction, PD: peritoneal dialysis

Table 3) Right ventricular 2-Dimensional and M-Mode echocardiographic parameters	Table 3) Right ventricular 2-Dimensional and M-Mode echocardiographic parameters	Table 3) Right ventricular 2-Dimensional and M-Mode echocardiographic parameters	Table 3) Right ventricular 2-Dimensional and M-Mode echocardiographic parameters	Table 3) Right ventricular 2-Dimensional and M-Mode echocardiographic parameters
	Controls (n=40)	**PD (n=40)**	**HD (n= 40)**	**p value**
RA longitudinal diameter (mm)	44.41 ± 4.30	45.39 ± 5.38	44.05 ± 5.93	0.585
RA minor diameter (mm)	34.63 ± 4.94	34.98 ± 5.95	35.61 ± 6.28	0.747
RA area (mm^2)	12.90 ± 2.12	13.17 ± 3.13	13.06 ± 4.92	0.946
RV basal diameter (mm)	27.55 ± 3.005	28.46 ± 4.09	30.75 ± 5.10*	**0.002**
RV FAC (%)	43.36 ± 7.67	39.60 ± 9.77	39.34 ± 10.23	0.110
TAPSE (mm)	25.57 ± 4.33	22.60 ± 4.75*	17.99 ± 3.91§	**<0.001**
Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.008 for TAPSE, p=0.002 for RV basal diameter § different from control and peritoneal dialysis, p<0.001 and p<0.001, respectively for TAPSE; p=0.002 and p=0.041, respectively for RV basal diameter BP: Blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RA: Right atrium, RV: Right ventricle, TAPSE: Tricuspid annular plane systolic excursion	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.008 for TAPSE, p=0.002 for RV basal diameter § different from control and peritoneal dialysis, p<0.001 and p<0.001, respectively for TAPSE; p=0.002 and p=0.041, respectively for RV basal diameter BP: Blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RA: Right atrium, RV: Right ventricle, TAPSE: Tricuspid annular plane systolic excursion	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.008 for TAPSE, p=0.002 for RV basal diameter § different from control and peritoneal dialysis, p<0.001 and p<0.001, respectively for TAPSE; p=0.002 and p=0.041, respectively for RV basal diameter BP: Blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RA: Right atrium, RV: Right ventricle, TAPSE: Tricuspid annular plane systolic excursion	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.008 for TAPSE, p=0.002 for RV basal diameter § different from control and peritoneal dialysis, p<0.001 and p<0.001, respectively for TAPSE; p=0.002 and p=0.041, respectively for RV basal diameter BP: Blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RA: Right atrium, RV: Right ventricle, TAPSE: Tricuspid annular plane systolic excursion	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.008 for TAPSE, p=0.002 for RV basal diameter § different from control and peritoneal dialysis, p<0.001 and p<0.001, respectively for TAPSE; p=0.002 and p=0.041, respectively for RV basal diameter BP: Blood pressure, HD: hemodialysis, PD: peritoneal dialysis, RA: Right atrium, RV: Right ventricle, TAPSE: Tricuspid annular plane systolic excursion

Table 4. Right ventricular Doppler echocardiographic parameters	Table 4. Right ventricular Doppler echocardiographic parameters	Table 4. Right ventricular Doppler echocardiographic parameters	Table 4. Right ventricular Doppler echocardiographic parameters	Table 4. Right ventricular Doppler echocardiographic parameters
	Controls (n=40)	**PD (n=40)**	**HD (n=40)**	**p value**
E (m/s)	54.80 ± 13.01	60.35 ± 13.61	65.74 ± 18.49*	**0.007**
A (m/s)	48.73 ± 14.76	61.85 ± 19.45*	62.85 ± 19.45*	**<0.001**
Ea (m/s)	12.61 ± 3.30	10.77 ± 3.61	10.45 ± 3.93	0.018
Aa (m/s)	16.01 ± 4.09	16.20 ± 4.09	14.79 ± 4,03	0.250
E/A	1.19 ± 0.34	1.04 ± 0.33	1.09 ± 0.28	0.106
E/Ea	4.57 ± 1.46	6.38 ± 3.06*	6.94 ± 2.88*	**<0.001**
Sa (cm/s)	14.35 ± 2.34	14.07 ± 3.71	11.79±2.70§	**0.001**
PASP (mmHg)	25.33 ± 4.82	23.89 ± 8.21	28.71 ± 6.90§	**0.006**
RV MPI	0.27 ± 0.14	0.29 ± 0.11	0.47 ± 0.21 §	**<0.001**

Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.006 for E velocity; p=0.004 and p=0.001, respectively for A velocity; $p<0.001$ and p=0.06 respectively for E/Ea § different from control and peritoneal dialysis, $p<0.001$ and p=0.002, respectively for Sa; p=0.071 and p=0.005, respectively for PASP; $p<0.001$ for RV MPI A: Late tricuspid inflow velocity, Aa: Late diastolic velocity of tricuspid lateral annulus, E: Early tricuspid inflow velocity, Ea: Early diastolic velocity of tricuspid lateral annulus, HD: hemodialysis, PD: peritoneal dialysis, RV MPI: Right ventricular myocardial performance index, PASP: Pulmonary artery systolic pressure, Sa: Systolic velocity of tricuspid lateral annulus	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.006 for E velocity; p=0.004 and p=0.001, respectively for A velocity; $p<0.001$ and p=0.06 respectively for E/Ea § different from control and peritoneal dialysis, $p<0.001$ and p=0.002, respectively for Sa; p=0.071 and p=0.005, respectively for PASP; $p<0.001$ for RV MPI A: Late tricuspid inflow velocity, Aa: Late diastolic velocity of tricuspid lateral annulus, E: Early tricuspid inflow velocity, Ea: Early diastolic velocity of tricuspid lateral annulus, HD: hemodialysis, PD: peritoneal dialysis, RV MPI: Right ventricular myocardial performance index, PASP: Pulmonary artery systolic pressure, Sa: Systolic velocity of tricuspid lateral annulus	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.006 for E velocity; p=0.004 and p=0.001, respectively for A velocity; $p<0.001$ and p=0.06 respectively for E/Ea § different from control and peritoneal dialysis, $p<0.001$ and p=0.002, respectively for Sa; p=0.071 and p=0.005, respectively for PASP; $p<0.001$ for RV MPI A: Late tricuspid inflow velocity, Aa: Late diastolic velocity of tricuspid lateral annulus, E: Early tricuspid inflow velocity, Ea: Early diastolic velocity of tricuspid lateral annulus, HD: hemodialysis, PD: peritoneal dialysis, RV MPI: Right ventricular myocardial performance index, PASP: Pulmonary artery systolic pressure, Sa: Systolic velocity of tricuspid lateral annulus	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.006 for E velocity; p=0.004 and p=0.001, respectively for A velocity; $p<0.001$ and p=0.06 respectively for E/Ea § different from control and peritoneal dialysis, $p<0.001$ and p=0.002, respectively for Sa; p=0.071 and p=0.005, respectively for PASP; $p<0.001$ for RV MPI A: Late tricuspid inflow velocity, Aa: Late diastolic velocity of tricuspid lateral annulus, E: Early tricuspid inflow velocity, Ea: Early diastolic velocity of tricuspid lateral annulus, HD: hemodialysis, PD: peritoneal dialysis, RV MPI: Right ventricular myocardial performance index, PASP: Pulmonary artery systolic pressure, Sa: Systolic velocity of tricuspid lateral annulus	Data is presented as mean ± standard deviation for continuous variables. P values refer to ANOVA tests. * different from control, p=0.006 for E velocity; p=0.004 and p=0.001, respectively for A velocity; $p<0.001$ and p=0.06 respectively for E/Ea § different from control and peritoneal dialysis, $p<0.001$ and p=0.002, respectively for Sa; p=0.071 and p=0.005, respectively for PASP; $p<0.001$ for RV MPI A: Late tricuspid inflow velocity, Aa: Late diastolic velocity of tricuspid lateral annulus, E: Early tricuspid inflow velocity, Ea: Early diastolic velocity of tricuspid lateral annulus, HD: hemodialysis, PD: peritoneal dialysis, RV MPI: Right ventricular myocardial performance index, PASP: Pulmonary artery systolic pressure, Sa: Systolic velocity of tricuspid lateral annulus

Table 5. Correlations between RV dysfunction score and Echocardiographic/Clinic parameters

Left ventricular echocardiographic parameters	Left ventricular echocardiographic parameters Correlation coefficient	Left ventricular echocardiographic parameters p value	Right ventricular echocardiographic parameters	Right ventricular echocardiographic parameters Correlation coefficient	Right ventricular echocardiographic parameters p value
LVEDD (mm)	-0.114	0.214	RA longitudinal diameter (mm)	0.012	0.894
LVESD (mm)	0.053	0.564	RA minor diameter (mm)	-0.129	0.161
LVMI (g/m^2)	0.080	0.386	RA area (mm^2)	-0.58	0.532
LAVI (mL/m^2)	0.021	0.821	RV basal diameter (mm)	0.178	0.052
LVOT (mm)	**0.274**	**0.002**			
E (m/s)	-0.031	0.736			
A (m/s)	0.060	0.520	E (m/s)	0.154	0.092
Em (m/s)	**-0.184**	**0.044**	A (m/s)	0.145	0.115
E/A	-0.062	0.500	**Ea (m/s)**	**-0.376**	**<0.001**
E/Em	**0.218**	**0.017**	**Aa (m/s)**	**-0.275**	**0.002**
Clinical parameters	Clinical parameters Correlation coefficient	Clinical parameters P value	E/A	-0.070	0.448
			E/Ea	**0.390**	**<0.001**
Age (years)	**0.191**	**0.037**	PASP (mmHg)	0.110	0.232
Body mass index (kg/m^2)	-0.120	0.193			
Systolic BP (mmHg)	-0.066	0.474			
Diastolic BP (mmHg)	-0.152	0.097			

A: Late mitral/tricuspid inflow velocity, BP: blood pressure, E: Early mitral/tricuspid inflow velocity, Ea: Early diastolic velocity of tricuspid lateral annulus, Em: Early diastolic velocity of mitral annulus, LVEDD: Left ventricular end-diastolic diameter, LVESD: Left ventricular end-systolic diameter, LVMI: Left ventricular mass index, LAVI: Left atrial volume index, LVOT: Left ventricular outflow tract, LVEF: Left ventricular ejection fraction, PASP: Pulmonary artery systolic pressure, RA: Right atrium, RV: Right ventricle, TAPSE: Tricuspid annular plane systolic excursion

Table 6. Independent variables associated with right ventricular dysfunction

	OR	95 % CI Lower	95 % CI Upper	p
Hemodialysis	2.097	3.144	21.920	<0.001
Right Aa velocity	-0.154	0.761	0.966	.012
Age	0.062	1.024	1.106	0.002