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ORIGINAL ARTICLE

Echocardiographic assessment of right ventricular function in peritoneal dialysis patients

Periton diyalizi hastalarında sağ ventrikül fonksiyonlarının ekokardiyografik olarak değerlendirilmesi

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ABSTRACT

Objective: Cardiovascular disease is the leading cause of mortality in patients undergoing dialysis. Most of the available studies focus on left ventricular (LV) function in peritoneal dialysis (PD) patients; data about the effect of PD on right ventricular (RV) function are scarce. The aim of this study was to evaluate echocardiographic parameters of the RV in patients with end-stage renal disease (ESRD) undergoing PD.

Methods: A total of 73 individuals were grouped as follows: PD patients (n=36) and healthy controls (n=37). Echocardiography of the RV was performed in all of the patients using tissue Doppler imaging (TDI).

Results: The LV mass index (LVMI), left atrial (LA) diameter, posterior wall, and interventricular septum thicknesses were significantly greater in the PD group. The LV peak late diastolic atrial contraction (A) velocity was higher, and the peak early diastolic (E) velocity and the early diastolic velocity of the lateral mitral annulus (Em) were lower in the PD group compared with the control group. The right atrial (RA) diameter, RA area, RV fractional area change, RV myocardial performance index, and pulmonary vascular resistance values were similar in both groups, whereas the tricuspid annular plane systolic excursion (TAPSE) value was lower in the PD patients. The RV E; early diastolic (Ea), late diastolic (Aa), and systolic (Sa) velocities; deceleration time; and tricuspid regurgitation velocity were also similar in the 2 groups. Only the RV A velocity and the Ea/Aa ratio were significantly higher in the PD group, and the E/A ratio was lower in the PD group than in the control group.

Conclusion: The results of conventional and TDI echocardiography indicated that RV systolic and diastolic functions were preserved in PD patients.

ÖZET

Amaç: Kardiyovasküler hastalıklar diyaliz tedavisi gören hastalarda önde gelen mortalite nedenidir. Çalışmaların çoğunun periton diyalizi hastalarında sol ventrikül (SoV) fonksiyonlarına odaklanmasına rağmen, periton diyalizinin sağ ventriküler (SaV) fonksiyonlara etkisi konusunda yeterli bilgi yoktur. Biz çalışmamızda periton diyalizi tedavisi gören son dönem böbrek yetmezliği (SDBY) hastalarında SaV ekokardiyografik parametrelerini incelemeyi amaçladık.

Yöntemler: İki grupta toplam 73 hasta incelendi: 36 periton diyalizi hastası ve 37 sağlıklı kontrol grubu. Tüm hastalara SaV doku Doppler görüntülemeyi de içeren ekokardiyografik inceleme yapıldı.

Bulgular: SoV kitle indeksi, sol atriyum çapları, arka duvar ve interventriküler septum kalınlıkları periton diyalizi hastalarında anlamlı olarak artmış saptandı. Periton diyalizi grubunda kontrol grubuna kıyasla SoV A velositesi anlamlı olarak yüksek, E ve Em velositeleri düşük olarak saptandı. Sağ atriyal çaplar, sağ atriyum alanı, SaV fraksiyonel alan değişimi, SaV miyokard performans indeksi, pulmoner vasküler rezistans açısından gruplar arasında anlamlı fark gözlenmezken, triküspit anüler plan sistolik ekskürsiyon (TAPSE) değeri periton diyalizi grubunda düşük saptandı. SaV E, Ea, Aa, Sa hızları, deselerasyon zamanı ve triküspit regürjitasyon hızları da her iki grupta benzerken, SaV A hızı ve Ea/Aa oranı periton diyalizi grubunda anlamlı olarak yüksek, E/A oranı ise düşük saptandı.

Sonuç: Konvansiyonel Doppler ve doku Doppler ekokardiyografi ile değerlendirilen SaV sistolik ve diyastolik fonksiyonları periton diyalizi hastalarında korunmuş olarak saptandı.

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End stage renal disease (ESRD) is associated with significantly increased morbidity and mortality. Cardiovascular diseases are the most common cause of death in this group of patients.[1] Several studies have demonstrated that left ventricular (LV) systolic and diastolic functions deteriorated in patients with chronic renal disease and this was associated with poorer clinical outcomes.[2] However, most of the available studies have focused on LV function in dialysis patients; data about right ventricular (RV) function are lacking. A few studies that have investigated the impact of hemodialysis (HD) on RV functions have reported deterioration of RV systolic and diastolic functions in HD patients.[3–5] A retrospective study in which Paneni et al.[6] investigated the impact of different dialysis treatments on RV function revealed that compared with peritoneal dialysis (PD), HD increased the risk of RV dysfunction, particularly in the presence of brachial arteriovenous fistula. But the impact of PD treatments on RV functions has not been fully investigated.

Although there are some difficulties with echocardiographic evaluation of the RV due to the complex anatomy and retrosternal localization, assessment of RV function with 2-dimensional and tissue Doppler imaging (TDI) is an accurate and reproducible method of detecting preclinical ventricular abnormalities.[7]

The aim of this was to use transthoracic echocardiography to assess RV function in patients with ESRD pursuing PD treatment.

METHODS

This is a cross-sectional, observational study that included 36 (15 women, 21 men; mean age: 52.2±14.1 years) patients with ESRD undergoing PD. They were recruited from the PD unit of Antalya Research and Training Hospital between May 2014 and May 2015. A control group of 37 healthy, age-matched volunteers was also included. Every participant provided informed consent and all of the diagnostic criteria were approved by the local ethics committee.

The exclusion criteria were defined by clinical or echocardiographic evidence of ischemic heart disease, LV systolic dysfunction with an ejection fraction (EF) of less than 50%, valvulopathy, or previous renal transplantation. 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 thorough clinical evaluation, laboratory evaluation, and radiological assessment. Blood samples were obtained in the morning after an overnight fast. Blood pressure, heart rate, demographic characteristics, clinical history, laboratory parameters, and medication use were recorded. Routine serum biochemical variables, including glucose, serum creatinine, calcium, phosphorus, albumin, complete blood count, high-sensitive C-reactive protein, and a lipid profile levels were analyzed. A 12-lead electrocardiogram (ECG) was also performed.

Abbreviations:

A	*Peak late diastolic velocity*
Aa	*Late diastolic velocity of the lateral tricuspid annulus*
BP	*Blood pressure*
DT	*Deceleration time*
E	*Peak early diastolic velocity*
Ea	*Early diastolic velocity of the lateral tricuspid annulus*
ECG	*Electrocardiogram*
Em	*Early diastolic velocity of the lateral mitral annulus*
EF	*Ejection fraction*
ET	*Ejection time*
ESRD	*End-stage renal disease*
FAC	*Fractional area change*
HD	*Hemodialysis*
ICVT	*Isovolumetric contraction time*
IVSEDD	*Interventricular septum thickness at end-diastol*
IVRT	*Isovolumetric relaxation time*
LA	*Left atrial*
LV	*Left ventricular*
LVEDD	*LV end-diastolic diameter*
LVESD	*LV end-systolic diameter*
LVM	*LV mass*
LVMI	*LV mass index*
MPI	*Myocardial performance index*
PD	*Peritoneal dialysis*
PWEDD	*Posterior wall thickness at end-diastole*
RA	*Right atrial*
RV	*Right ventricular*
RVEF	*RV ejection fraction*
RVFAC	*RV fractional area change*
Sa	*Peak systolic velocity of the lateral tricuspid annulus*
TAPSE	*Tricuspid annular plane systolic excursion*
TCO	*Tricuspid valve closure and opening time*
TDI	*Tissue Doppler imaging*

Echocardiography

Echocardiographic examinations were performed with a 2-4 MHz transducer attached to a Vivid S5 echocardiography machine (GE Healthcare, Inc. Chicago, IL, USA). A single-lead ECG was recorded continuously during an examination in the left lateral decubitus position. The analysis was performed according to the guidelines of the American Society of Echocardiography recommendations.

The left ventricular end-diastolic and end-systolic diameters (LVEDD, LVESD) and the end-diastolic interventricular septum and posterior wall thicknesses (IVSEDD, PWEDD) were measured in the paraster-

nal long axis view.[8] The EF was calculated according to the Teichholz formula.[9] The left atrial (LA) diameter was calculated in the parasternal long axis and apical 4-chamber views. The IVSEDD, PWEDD, and internal diameters were used to calculate LV mass (LVM) using the following equation: LVM = 1.04 x 0.8 [(LV wall thicknesses+internal dimension) - (internal dimension)] + 10.6.[10] To evaluate the diastolic functions of the LV, the mitral inflow velocities were evaluated from the apical 4-chamber view. The early diastolic velocity of the lateral mitral annulus (Em) was recorded with tissue Doppler imaging (TDI).

The right ventricular diameters were measured in the parasternal long axis and apical 4-chamber views. The systolic pulmonary arterial pressure, fractional area change (FAC), systolic myocardial velocity of the lateral tricuspid annulus (Sa) velocity, tricuspid annular plane systolic excursion (TAPSE), TDI-derived myocardial performance index (MPI), tricuspid E wave velocity, A wave velocity, deceleration time (DT), E/A ratio, the early diastolic velocity of the lateral tricuspid annulus (Ea) velocity, the late diastolic velocity of the lateral tricuspid annulus (Aa) and the Ea/Aa ratio were measured.

The maximal tricuspid regurgitation velocity was measured using continuous wave Doppler echocardiography in the apical 4-chamber view. Systolic pulmonary pressure was calculated as follows: 4 x (tricuspid systolic jet)^2 + right atrial pressure.

The 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.[11] On the TDI images, peak annular systolic velocity (Sa), Ea and Aa velocities, and systolic velocity duration were measured as ejection time (ET), isovolumetric relaxation time (IVRT, time between the end of ET and the beginning of Ea), and isovolumetric contraction time (IVCT, time between the end of Aa and the beginning of ET). Tricuspid valve closure and opening time (TCO), which was measured from the cessation of the Am wave to the beginning of the Em wave, encompassed the IVCT, ET, and IVRT. The TDI-derived MPI, as a global estimate of both systolic and diastolic functions of the RV, was calculated with the formula TDI - MPI = (TCO-ET) / ET.[12]

The 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.

The 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. RV FAC was calculated using the formula FAC = (end-diastolic area – end-systolic area) / end-diastolic area x 100.[13]

Statistical analysis

The data were tabulated, coded, and then analyzed using SPSS Statistics for Windows, Version 17.0 (SPSS, Inc., Chicago, IL, USA). Continuous variables were tested for normal distribution with the Kolmogorov-Smirnov test. Continuous variables were presented as mean±SD and compared using Student's t-test if

Table 1. Characteristics of the population

Variables	Peritoneal dialysis	Control	*p*
Age (years), (Mean±SD)	52.2 (14.1)	47.1 (7.7)	0.730
Gender (male), n (%)	21 (58.3)	13 (35.1)	0.047
Body mass index (kg/m^2) (Mean±SD)	28.08 (5.4)	29.20 (5.3)	0.375
Diabetes mellitus, n (%)	9 (40.9)	5 (15.2)	0.032
Hypertension, n (%)	27 (81.8)	7 (21.2)	<0.001
Systolic blood pressure, mm Hg, (Mean±SD)	129.7 (17.8)	116.6 (15.3)	0.002
Diastolic blood pressure, mm Hg, (Mean±SD)	75.58 (13.3)	74.54 (89.7)	0.716
Pulse rate, beats/m, (Mean±SD)	80.0 (14.6)	78.3 (9.1)	0.562
Duration of dialysis, months, (Mean±SD)	44.4 (34.3)	–	–

Table 2. Laboratory parameters

	Peritoneal dialysis	Control	*p*
Ferritin (ng/ml)	328.18±288.32	35.73±57.84	<0.001
Hemoglobin (g/dl)	10.66±2.38	15.38±10.68	0.140
Albumin (g/dl)	3.48±0.42	4.32±0.30	<0.001
Calcium (mg/dl)	9.02±0.87	9.50±0.48	0.006
Phosphorus (mg/dl)	4.88±1.17	3.50±0.47	<0.001
Prealbumin (mg/dl)	33.91±9.65	25.85±4.32	<0.001
Protein (g/dl)	6.74±0.52	7.28±0.45	<0.001
Calcium and phosphorus	43.89±10.48	33.45±4.92	<0.001
Creatinine (mg/dl)	8.06±3.00	0.85±0.15	<0.001

Table 3. Left ventricular parameters

	Peritoneal dialysis	Control	*p*
Left ventricular mass index (gr/m²)	128.47±38.97	80.41±24.73	<0.001
E (m/s)	0.70±0.18	0.79±0.18	0.038
A (m/s)	0.91±0.21	0.70±0.24	<0.001
Early diastolic myocardial velocity (cm/s)	7.01±2.47	9.34±2.64	<0.001
Late diastolic myocardial velocity (cm/s)	10.14±2.87	9.29±2.21	0.162
Deceleration time	258.86±79.51	238.24±70.64	0.245
E/A	0.65±0.27	0.56±0.26	0.151
Em/Am	11.29±5.57	9.14±3.54	0.054
Interventricular septum end diastolic diameter (mm)	12.86±2.07	10.00±1.62	<0.001
Posterior wal end diastolic diameterl (mm)	12.22±1.57	9.81±1.51	<0.001
Left ventricular end diastolic diameter (mm)	46.78±5.44	45.03±4.32	0.132
Left ventricular end systolic diameter (mm)	30.25±5.43	27.59±3.16	0.013
Left ventricular outflow tract (mm)	22.23±3.23	20.59±2.42	0.017
Left atrium anteroposterior diameter (mm)	40.26±4.68	33.92±4.17	<0.001
Left atrium long axis diameter (mm)	51.08±5.97	46.83±5.27	<0.002
Left atrium short axis diameter (mm)	41.42±5.80	36.17±4.46	<0.001
Left ventricle ejection fraction (%)	63.47±5.32	64.59±1.38	0.219

E: Peak early diastolic mitral inflow velocity; A: Peak late diastolic mitral inflow velocity; Em: Early diastolic myocardial velocity; Am: Late diastolic myocardial velocity.

normally distributed or presented as median (25^{th}-75^{th} percentiles) and compared using the Mann-Whitney U test if not compatible with normal distribution. Categorical variables were summarized as percentages and compared with a chi-square test. A 2-tailed p value <0.05 was considered statistically significant.

RESULTS

The demographic and clinical characteristics of our study population are shown in Table 1.

The groups were similar in terms of age, but different in terms of gender [52.2±14.1 years vs. 47.1±7.7 years; p=0.73 and 21 males (58.3%) vs. 13 males (35.1%); p=0.047]. The body mass index values of the groups were similar (28.08±5.4 kg/m² vs. 29.2±5.3 kg/m²; p=0.375). The presence of diabetes was significantly greater in the PD group [9 patients (40.9%) vs. 5 patients (15.2%); p=0.032)] as well as hypertension

Table 4. Right ventricular M mode and 2-dimensional findings

	PD	Control	*p*
RA long axis (mm)	45.37±5.59	44.14±4.43	0.312
RA minor axis (mm)	34.97±6.42	33.94±4.61	0.444
RA area (cm²)	16.41±15.97	12.97±2.33	0.234
TAPSE (mm)	22.54±5.80	25.91±4.26	0.006
RVFAC (%)	40.79±13.25	42.84±7.6	0.428
Lateral TDI MPI	0.22±0.18	0.27±0.15	0.252
PVR (dyn*sn/cm^5)	1.09±0.51	1.18±	0.472

Lateral TDI MPI: Tissue Doppler imaging of myocardial performance index at lateral tricuspid annulus; PD: Peritoneal dialysis; RA: Right atrium; RV-FAC: Right ventricular fractional area change; TAPSE: Tricuspid annular plane systolic excursion.

Table 5. Right ventricular Doppler findings

	PD	Control	*p*
E (m/s)	0.61±0.15	0.55±0.13	0.076
A (m/s)	0.62±0.16	0.48±0.15	<0.001*
Ea (cm/s)	11.17±3.75	12.75±3.33	0.063
Aa (cm/s)	16.43±4.23	15.99±4.26	0.670
E/A	1.04±0.35	1.22±0.34	0.036
Ea/Aa	6.27±3.19	4.56±1.49	0.004
DT (ms)	287±89.98	276.17±89.98	0.591
Sa (cm/s)	15.48±7.16	14.28±2.39	0.342
TR vel (cm/s)	2.13±0.62	2.26±0.34	0.515

A: Peak late diastolic tricuspid inflow velocity; Aa: Late diastolic velocity of tricuspid lateral annulus; DT: Deceleration time; E: Peak early diastolic tricuspid inflow velocity; Ea: Early diastolic velocity of tricuspid lateral annulus; PD: Peritoneal dialysis; Sa: Systolic myocardial velocity of tricuspid annulus; TR vel: Tricuspid regurgitation flow velocity. *P value <0.05.

[27 patients (81.8%) vs. 7 patients (21.2%); p<0.001]. There was no significant difference between the PD and control groups with respect to diastolic blood pressure (BP) (75.58±13.3 mm Hg vs. 74.54±89.7 mm Hg; p=0.716), whereas systolic BP and heart rate were significantly higher in the PD group (129.7±17.8 mm Hg vs. 116.6±15.3 mm Hg; p=0.002 and 80.0±14.6 beats/min vs. 78.3±9.1 beats/min; p=0.002, respectively). The ESRD patients had been following a PD program for a mean of 44.4±34.3 months. In the laboratory tests, creatinine, phosphorus, and ferritin levels were significantly higher in the ESRD patients; however, calcium, albumin, total protein, and hemoglobin levels were found to be significantly lower (Table 2).

There was no significant difference between the groups with respect to LVEDD or LVEF; however the LVESD, LV outflow tract diameter, LV mass index (LVMI), LA diameter, IVSEDD, and PWEDD were significantly greater in the PD group. The LV A velocity was higher, while the E and Em velocities were lower in the PD group compared with the control group, whereas the LV Am velocity, DT, E/A and Em/Am ratios were similar between the groups (Table 3).

The right atrial (RA) diameters, RA area, RV FAC, MPI, and pulmonary vascular resistance were also similar in both groups, but the TAPSE values were significantly lower in the PD group (Table 4).

The RV E, Ea, and Sa velocities; E/A ratio; DT; and tricuspid regurgitation velocity were similar in the 2 groups; however, the A velocity and Ea/Aa ratio were significantly higher in the PD group than in the control group (Table 5).

DISCUSSION

Cardiovascular disease is the leading cause of mortality in patients undergoing dialysis, accounting for 50% of deaths.[14] The high risk of cardiovascular death in individuals with ESRD is related to several factors. These comprise traditional and non-traditional risk factors; toxic, metabolic, and vascular factors; and considerations like hypervolemia, hypertension, and anemia.[15] It has been demonstrated in several studies that LV hypertrophy, LV dilatation, reduced EF, and diastolic dysfunction can develop as a result of these factors. However, data on the prevalence of RV dysfunction in patients undergoing chronic dialysis, especially PD, are still lacking.

A surgical arteriovenous fistula causes a left-to-right shunt, leading to chronic volume overload, independent of the increase in total body water, thus worsening RV overload in HD patients.[16] There are few studies that have examined the impact of HD on RV function. Mohamed et al.[3] reported that ESRD and arteriovenous fistula were associated with RV dysfunction and a significantly lower RVEF. Karavelioğlu et al.[2] reported that RV systolic and diastolic functions were disrupted in HD patients without hypertension or diabetes mellitus. Momtaz et al.[4] also confirmed a high prevalence of pulmonary hypertension and subclinical RV dysfunction among

HD patients. Paneni et al.[6] reported in a retrospective study that RV dysfunction was significantly higher in HD patients compared with PD patients, particularly in the presence of a brachial arteriovenous fistula.

Akyüz et al.[17] investigated the effect of decreased preload on RV systolic function in HD patients using echocardiographic parameters. They found that RV Sa velocity was independent of preload, whereas RV FAC, MPI, and TAPSE values were dependent on preload. Akkaya et al.[18] examined the effects of HD on RV echocardiographic parameters in patients with ESRD using echocardiography before and after HD. They reported that the TAPSE value showed a significant increase after HD, but the RV MPI and Sa values were not changed significantly by dialysis. The TAPSE value was preload dependent, but the MPI and S' values were not preload dependent. The MPI and Sa values were accepted as more reliable parameters for assessing RV systolic function.

PD without an arteriovenous fistula, which can increase blood circulation pressure, has been recommended for uremic patients. Using this approach, the body volume changes occur slowly, and there is minimal risk of developing cardiovascular disease. However, most of the available studies have focused their attention on LV dysfunction in ESRD patients; the impact of PD treatment on RV functions has not yet been fully investigated.

The aim of this study was to assess RV function in patients on PD in comparison with a control group.PD patients in our study showed a significant increase in LVMI compared with the controls (128.47±38.97 vs. 80.41±24.73; p<0.001). Also, it was found that PD patients demonstrated a statistically significant increase in both IVSEDD (12.86±2.07 vs. 10.00±1.62; p<0.001) and PWEDD (12.22±1.57 vs. 9.81±1.51; p<0.001) compared with controls. There was no significant difference in the LVEF between the PD group and the control group. The LV A velocity was higher, whereas the E and Em velocities were lower in the PD group, indicating the diastolic dysfunction of the LV. These findings were similar to those of previous studies.

No difference in RV dimensions was seen between the 2 groups of our study. TAPSE, the annular motion of the RV toward the apex, is a good parameter to evaluate RV function and it correlates closely with RVEF and RVFAC in a variety of patient populations.[19] We found that our ESRD patients undergoing PD had lower TAPSE values compared with control subjects (22.54±5.80 vs. 25.91±4.26; p=0.006). RVFAC is another measure of RV systolic function that has been shown to correlate well with RVEF using magnetic resonance imaging.[20] No significant difference in RVFAC values was found between the 2 groups in our study. MPI is a parameter that is less affected than heart rate, preload, and afterload.[21] In our study, there was no statistically significant difference between the patients and the control group in terms of MPI value, reflecting both RV systolic and diastolic functions. Furthermore, no significant difference was found in lateral TDI Sa values, reflecting RV systolic parameters, between the groups in our study; therefore, when we evaluated RV function globally, we didn't detect significant deterioration.

Among the parameters reflecting RV diastolic function, the RV E velocity, E/A ratio, Ea, and DT were similar between the 2 groups; only the A velocity and Ea/Aa ratio were higher in the PD group. There was also no difference in tricuspid regurgitation velocity between the groups.

Limitations

This was a cross-sectional study that included a relatively small number of ESRD patients undergoing PD. Additional limitations include the lack of using cardiac magnetic resonance imaging for RV functional assessment and the Simpson method for the determination of LVEF.

Conclusion

The results of this study demonstrated that RV systolic and diastolic functions as estimated using conventional Doppler and TDI echocardiography were preserved in PD patients. This finding highlights the importance of selecting PD as the dialysis technique for ESRD patients at risk of developing right heart failure. These results should be confirmed by additional, larger studies.

Ethics Committee Approval: The study was approved by the Ethics Committee of Antalya Training and Research Hospital (approval date: 28.02.2013 approval no.: 15/7).

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