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Echocardiographic evaluation of right heart functions in hemodialysis patients

Hemodiyaliz hastalarında sağ kalp fonksiyonlarının ekokardiyografik olarak değerlendirilmesi

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Abstract

Aim: Volume load assessment is an important problem in patients with chronic renal failure (CRF). Apart from classical volume assessment methods, the number of studies on echocardiographic evaluation of right heart functions is limited. In this study, we aimed to evaluate right heart functions echocardiographically in end-stage renal failure patients receiving hemodialysis (HD) therapy and its utility in volume load determination.

Methods: This case-control study included 49 patients receiving HD treatment as the study group. The control group consisted of 46 healthy individuals whose age and gender were matched. Echocardiographic evaluation was performed for all participants. Tricuspid annular plane systolic excursion (TAPSE), systolic pulmonary artery pressure (SPAB), tricuspid E wave velocity, A wave velocity, E / A ratio, right ventricular ejection fraction (RVEF) and left ventricular ejection fraction (LVEF) were measured.

Results: Right ventricular diastolic diameter (2.55 (0.3) vs 2.30 (0.29) respectively, $P<0.001$) SPAP (37.4 (8.3) vs 19 (6.8), $P<0.001$, respectively) were statistically significant higher in the study group, while TAPSE (1.61 (0.35) vs 2.09 (0.27), $P<0.001$, respectively), A rate, (0.63 (0.27) vs 0.45 (0.26), $P<0.001$, respectively), E / A ratio (0.93 (0.25) vs 1.37 (0.24), $P<0.001$, respectively) were significantly lower. Right ventricular (RV) E velocity was insignificantly lower in the study group ($P=0.523$). There were no statistically significant differences between the groups in terms of age, gender, and body mass index.

Conclusion: In our study, we found that TAPSE was low and SBAP and RV diastolic diameter were high in HD patients. We think that TAPSE and SPAB can be used together with conventional methods for evaluating hypervolemia in HD patients. Further studies are required to explore this clinical tool.

Keywords: Tricuspid annular plane systolic excursion, Systolic pulmonary artery pressure Hemodialysis, Right heart functions

Öz

Amaç: Volüm yükü değerlendirmesi kronik böbrek yetmezliği (KBY) hastalarında önemli bir sorundur. Klasik volüm değerlendirmesi yöntemleri dışında, sağ kalp fonksiyonlarının ekokardiyografik değerlendirmesi ile ilgili yapılmış çalışma sayısı kısıtlıdır. Bu çalışmada hemodiyaliz (HD) tedavisi alan son dönem böbrek yetmezliği hastalarında sağ kalp fonksiyonlarını ekokardiyografik olarak değerlendirmeyi ve volüm yükü tayininde kullanılabilirliğini amaçladık.

Yöntemler: Bu vaka kontrol çalışmasına, çalışma grubu olarak HD tedavisi alan 49 hasta alındı. Kontrol grubu olarak yaş, cinsiyet uyumu sağlanmış 46 sağlıklı birey alındı. Tüm katılımcıların ekokardiyografik olarak değerlendirmesi yapıldı. Triküspit anüler düzlem sistolik hareketi (TAPSE), sistolik pulmoner arter basıncı (SPAB), triküspit E dalga hızı, A dalga hızı, E/A oranı, sağ ventrikül ejeksiyon fraksiyonu (RVEF) ve sol ventrikül ejeksiyon fraksiyonu (LVEF) ölçüldü.

Bulgular: Sağ ventrikül diyastolik çapı (sırasıyla 2.55 (0.3) ve 2.30 (0.29), $P<0.001$) ve SPAP (37.4 (8.3) ve 19 (6.8), $P<0.001$), çalışma grubunda istatistiksel olarak anlamlı derecede yüksek bulundu. Çalışma grubunda TAPSE (sırasıyla 1.61 (0.35) ve 2.09 (0.27), $P<0.001$), A oranı, (sırasıyla 0.63 (0.27) ve 0.45 (0.26), $P<0.001$), E / A oranı (sırasıyla 0.93 (0.25) ve 1.37 (0.24), $P<0.001$). Çalışma grubunda sağ ventrikül E hızı daha düşüktü ancak istatistiksel olarak anlamlı değildi ($P=0.523$). Gruplar arasında yaş, cinsiyet ve vücut kitle indeksi açısından istatistiksel olarak anlamlı fark yoktu.

Sonuç: Çalışmamızda, HD hastalarında TAPSE'nin düşük, SBAP'nin ve sağ ventrikül diyastolik çapının ise yüksek olduğunu tespit ettik. HD hastalarında TAPSE ve SPAB'nin, hipervolemiyi değerlendirmede geleneksel yöntemlerle birlikte kullanılabileceğini düşünüyoruz. Bu klinik aracı keşfetmek için daha ileri çalışmalar gereklidir.

Anahtar kelimeler: Triküspit anüler düzlem sistolik hareketi, Sistolik pulmoner arter basıncı, Hemodiyaliz, Sağ kalp fonksiyonları

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Introduction

Cardiovascular diseases (CVD) are still the most common cause of mortality and morbidity in chronic renal failure (CRF) patients [1-4]. Structural and functional abnormalities of the heart are common in patients with end-stage renal disease. The cause of this condition is pressure increase and excessive volume load [5-6]. In patients undergoing hemodialysis, the dry weight, considered to be the ideal weight, is described as the lowest weight that the patient can tolerate, not causing the development of hypotension and hypertension [7]. The first and most important step in the treatment of hypertension (HT) in patients with end-stage renal failure (ESRD) is the provision of hemodialysis (HD) proficiency and access to the patient's actual dry weight. In most hemodialysis patients, hypertension is caused by increased volume, which can be controlled by ultrafiltration. By reducing volume load, hypertension remains refractory in only 5-10% of patients [8]. Cardiovascular events were minimized and cardiovascular mortality and morbidity decreased when the fluid volume control was performed compared to ESRD patients using antihypertensive drugs. In the Tassin series, 20-year survival was 43% in patients who did not use antihypertensive drugs and who were normotensive with strict volume control only. Nevertheless, 5-year survival rate was 40-50% in patients receiving antihypertensive drugs [9]. Adequate and careful evaluation of cardiac functions of patients in this group is very important. The mortality rate in dialysis patients with hypervolemia is four to five times higher than those with normal blood volume [10]. Therefore, the right ventricular functions have recently gained importance in the determination of volume load in HD patients. Since the right ventricle (RV) dysfunction has been shown to be associated with mortality and morbidity in various pathologies, RV is now an important part of the heart that cannot be neglected. Evaluation of the RV has gained importance in recent years, especially after understanding its role in many diseases such as heart failure, pulmonary hypertension and congenital anomalies [11-17]. Many previous studies have shown impaired ventricular function in HD patients. In these studies, the focus is on the left ventricle (LV) functions. There are fewer studies on right heart functions. Several studies have shown impaired right ventricular systolic and diastolic function in HD patients. Pulmonary hypertension (PH) is defined as mean pulmonary artery pressure ≥25 mmHg [18]. Indeterminate or multifactorial mechanisms such as hormonal and metabolic disorders associated with chronic kidney disease (CKD) may cause pulmonary artery vasoconstriction and increased pulmonary vascular resistance in these patients [19]. Right heart catheterization (RHC) is still the gold standard for hemodynamic evaluation of right heart chambers [20-21]. However, as it is an interventional, time-consuming, costly and relatively difficult procedure to be repeated, it is not frequently used in patient follow-up. Therefore, transthoracic echocardiography with good correlation with RHC is recommended for PH screening using derived mean pulmonary artery pressure (mPAP) [22-24]. Similarly, tricuspid annular plane systolic excursion (TAPSE) on M-mod echocardiography provides a simple but specific method for systolic functional evaluation of the RV. And it correlates perfectly with the RV ejection fraction as assessed by radionuclide ventriculography [25]. The aim of this study was to compare the echocardiographically evaluated TAPSE and systolic pulmonary artery pressure (SPAB), an important indicator of RV functions, in HD patients and matched healthy controls.

Materials and methods

Study protocol

Patients between the ages of 18-85 years with sinus rhythm who received systemic HD treatment 3 times a week for at least 6 months were included in this single-center, case-control study. It was conducted on 49 patients followed in the hemodialysis unit of Bilecik State Hospital. 46 healthy individuals who were adjusted for age and gender made up the control group. Participants were informed about the study protocol and gave written informed consent. The local ethics committee approved this study.

The following were exclusion criteria: Patients with known coronary artery disease, Significant valvular disease, LV systolic dysfunction defined as an LVEF <50%, Pericardial disease, Congenital heart disease, Atrial fibrillation, Thyroid dysfunction, Patients with an active infection, Patients with chronic pulmonary disease, Moderate or severe anemia (Hg value <9 gr)

General evaluation and assessments

All participants underwent a detailed clinical, laboratory, and radiological evaluation. Blood pressure, heart rate, demographics, clinical history, laboratory parameters and drug use status were recorded. Blood samples were taken from the antecubital vein in the morning after overnight fasting. Routine serum biochemical variables were analyzed including glucose, serum creatinine, sodium, potassium, calcium, phosphorus, albumin, total protein, liver transaminases, complete blood count, C-reactive protein (CRP), parathyroid hormone (PTH) and lipid profile levels. A 12-lead electrocardiogram (ECG) was obtained from all participants.

Echocardiographic examinations were performed at the Department of Cardiology Echocardiography Laboratory using the EPIQ 7 echocardiography device (Philips, Amsterdam, The Netherlands). The analysis was performed according to the guidelines of the American Society of Echocardiography recommendations. Left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), interventricular septum thickness (IVS), posterior wall thickness (PW), left atrium (LA), Aortic diameter were measured using M-mode in parasternal long-axis imaging [26]. LVEF was measured by Teichoz method [27]. Mitral inflow velocities were evaluated from apical 4-chambered view to evaluate LV's diastolic functions. Right ventricular values were measured from the parasternal long axis and apical 4 chambers. TAPSE, SPAB, tricuspid E wave velocity, A wave velocity, E / A ratio were measured. TAPSE was measured from apical 4-chamber view by placing an M-mode cursor through the lateral tricuspid annulus and measuring the length of longitudinal motion of the annulus at peak systole [28]. SPAB was calculated as 4 x (tricuspid systolic jet) ² + right atrial pressure. Tricuspid regurgitation was measured using continuous-wave Doppler in

apical 4-chamber, parasternal short axis and parasternal long-axis views. The early (E) and late (A) RV inflow velocities were measured by pulsed-wave Doppler by the sample volume between the tricuspid valve in the apical 4-chamber view.

Statistical analysis

Statistical analysis was performed using SPSS version 18.0 (Statistical Package for Social Sciences Inc., Chicago, Illinois, USA) for Windows. Categorical variables were expressed as percentages. Numerical variables were presented as the arithmetic mean standard deviation. The differences between various groups were analyzed using Student's t-test for the parameters with normal distribution and the Mann–Whitney U test for those without normal distribution. The presence of a linear relationship between the normally distributed parameters was checked using Pearson's correlation test, while Spearman's correlation test was used for nonnormally distributed parameters. *P*-value <0.05 was considered statistically significant.

Results

Forty-nine HD patients and 46 healthy participants were included in the study. The mean weight was 65 (16.3) and mean body mass index (BMI) was 29 (3.4) kg / m^2. The mean systolic blood pressure of all participants was 130 (12) mmHg and the mean diastolic blood pressure was 79 (11) mmHg. Age group was similar, female participants were statistically higher in both the patient group and the control group (P<0.001). BMI was lower in the HD group, but this was not statistically significant. The number of patients with diabetes mellitus and HT history was significantly greater in the HD group (P<0.001 and P<0.001, respectively). Heart rate was higher in the HD group but not statistically significant (P=0.571). The mean HD duration was 56.3 (51.2) months. Demographic and clinical data are shown in Table 1.

As expected in laboratory tests, creatine, urea, phosphorus, potassium, PTH and ferritin values were significantly higher in the HD group. However, albumin, calcium, protein, hemoglobulin and platelet were found to be significantly lower. Although white blood cell (WBC) value was higher in the HD group, it was not statistically significant (Table 2).

LVEF and LVESD were similar in both groups. LVEDD, IVS, PW, LA measured by parasternal long axis were significantly higher in the HD group. RV end-diastolic diameter and SPAP values were significantly higher in the HD group after evaluation of right heart function (P<0.001 and P<0.001, respectively), and TAPSE, measured by M-mode technique, was significantly lower. The RV E velocity was insignificantly lower in HD group (P=0.523). The A velocity, and E/A ratio were significantly lower in the HD group (Table 3).

Table 1: Baseline characteristics of the participants

	Study group (n=49)	Control group (n=46)	*P*-value
Age	64.4 (12.0)	63.7 (8.9)	0.672
Male/ female, n (%)	32/17 (34.7/65.3)	31/15 (67.4/32.6)	<0.001
Hypertension, n (%)	17 (34.6)		
Diabetes mellitus, n (%)	22 (44.8)		
Weight (kg)	65 (17.3)	66 (15)	0.264
Body mass index, kg/ m^2	28.7 (3.5)	29.2 (3.3)	0.480
Pulse rate, beats/m, mean (SD)	80.1(14.7)	77.5(9.2)	0.571
Duration of dialysis, months	56.3 (51.2)		

SD: Standard deviation

Table 2: Laboratory values

	Study group	Control group	*P*-value
Hemoglobin (g/dl)	11.45 (1.26)	13.89 (1.57)	<0.001
Platelet (/mm3)	174.82 (61.50)	289.04 (91.44)	<0.001
WBC	7.84 (2.58)	7.16 (2.47)	0.131
Albumin (g/dl)	3.32 (0.35)	4.43 (0.45)	<0.001
Ferritin(ng/ml)	423 (298.32)	36.65 (59.82)	<0.001
Protein (g/dl)	6.53 (0.77)	7.35 (0.54)	<0.001
Calcium and phosphorus	43.92 (11.59)	33.62 (4.17)	<0.001
Glucose (mg/dl)	127.43 (47.11)	110.22 (8.50)	0.375
Creatinine (mg/dl)	6.56 (2.30)	0.97 (1.12)	<0.001
Urea	123.51 (30.39)	34.99 (41.78)	<0.001
ALT (IU/I)	15.59 (10.48)	22.11 (13.37)	0.004
AST (IU/I)	18 (13)	22 (16)	0.085
TSH	1.58 (0.89)	1.68 (0.87)	0.581
PTH	578.21 (453.45)	36.26 (5.72)	<0.001
CRP	12.15 (16.76)	7.78 (14.72)	0.010
LDL	85.48 (33.95)	125,48 (27.55	<0.001
HDL	38.30 (10.05)	45.49 (9.14	<0.001
TRG	167.85 (102.84)	161.57 (63.86	0.550
Total cholesterol (mg/dl)	157.09 (43.84)	206.45 (36.29	<0.001

ALT: alanine aminotransferase, AST: aspartate aminotransferase, CRP: C-reactive protein, HDL: high-density lipoprotein, LDL: low-density lipoprotein, PTH: parathyroid hormone, TRG: triglyceride, TSH: thyroid-stimulating hormone, WBC: white blood cell

Table 3: Echocardiographic findings

	Study group	Control group	*P*-value
Left ventricular EF (%)	61.07 (3.46)	62.54 (4.02)	0.324
LV end-diastolic diameter (cm)	4.91 (0.46)	4.63 (0.34)	<0.001
LV end systolic diameter (cm)	3.41 (0.47)	3.13 (0.47)	0.013
Interventricular septum (cm)	1.41 (0.38)	0.97 (0.19)	<0.001
Posterior wall (cm)	1.32 (0.29)	0.93 (0.16)	<0.001
LA diameter (cm)	3.80 (0.31)	3.41 (0.31)	<0.001
PA systolic pressure (mmHg)	37.4 (8.3)	19 (6.8)	<0.001
RV end-diastolic diameter (mm)	2.55 (0.39)	2.30 (0.29)	<0.001
TAPSE	1.61 (0.35)	2.09 (0.27)	<0.001
RV, E (m/s)	0.59 (0.21)	0.62 (0.22)	0.523
RV, A (m/s)	0.63 (0.27)	0.45 (0.26)	<0.001
RV, E/A	0.93 (0.25)	1.37 (0.24)	<0.001

EF: Ejection Fraction, LA: Left atrium, LV: Left ventricle, PA: Pulmonary artery, RV: Right ventricle, TAPSE: Tricuspid annular plane systolic excursion

Discussion

In our study, TAPSE used in the evaluation of right ventricle functions in patients receiving HD therapy was observed to be low and SPAB, high compared to healthy individuals. In case of hypervolemia, the excess blood distributes to the area with the highest compliance. Various parts of the cardiovascular system have different compliances. Compliance of the heart is quite high, but veins have the highest compliance. Therefore, in the presence of hypervolemia, the volumes of these sections increase. When the volume of the venous system and atrium increases, the cardiac output should increase according to the Starling forces. This phenomenon results in people with a normally functioning kidney to discard excess fluid. However, hemodialysis patients cannot successfully complete this process. Although various methods have been proposed for the determination of dry weight in these patients, the applicability and reliability of many of these are limited in clinical practice. We suggest that TAPSE and SPAP may be used in combination with the recommended methods for determining volume load in patients receiving chronic HD treatment. Heart and vascular diseases are the most important cause of mortality and morbidity in CRD patients [29]. Patients receiving dialysis treatment have a higher risk of CVD compared to the community of similar age and sexuality. High risk of cardiovascular death in individuals with ESRD is associated with many factors, which include toxic, metabolic, vascular factors, hypervolemia, hypertension and anemia. Several studies have shown that LV hypertrophy, LV dilatation, decreased EF and diastolic dysfunction may develop as a result of these factors. However, data on the prevalence of RV dysfunction in patients undergoing chronic dialysis are still lacking. Previous cardiac studies in CRF patients have often investigated LV systolic and diastolic functions. There are fewer

studies on RV functions. Diabetic nephropathy is the most common cause of CRF worldwide. Similarly, diabetic nephropathy was the most common etiologic factor in our study. Transthoracic echocardiography is a non-invasive method often used in the evaluation of right ventricular functions because it is easily achievable and inexpensive. However, the complexity of the geometric structure, the anatomical position, the roughness of the endocardial surface and the complex contraction mechanism of the right heart may complicate its evaluation by echocardiography. In order to minimize these difficulties, many echocardiographic methods are utilized together, and many studies are being conducted to develop new methods.

The basis of our study was to investigate the effect of volume burden on heart function by echocardiographic examination in HD patients. The patients included in the study did not have systolic heart dysfunction. In a study by López-Candales et al. [30], TAPSE, which represents the longitudinal functions of the right ventricle, was shown to decrease as a result of both right ventricular and left ventricular dysfunction, which was more pronounced in patients with right ventricular dysfunction. In our study, TAPSE was found to be significantly lower in patients receiving HD treatment. We thought that this could be due to the deterioration of right ventricular functions due to increased volume load. In the study of Kucukdurmaz et al. [31], it was reported that TAPSE decreased significantly in healthy individuals who donated 450 ml blood. In our study, TAPSE was low in HD patients with increased volume load. This was attributed to the hypervolemic status of the patients in our study and the normovolemic status of the subjects in the study of Kucukdurmaz [31]. Lopez-Candales et al. [32] showed that patients with advanced tricuspid regurgitation have a mechanical delay in RV, leading to low TAPSE values. Similarly, in our patient group, the RV diameter was wider than the control group and the rate of tricuspid regurgitation was higher. Akyüz et al. investigated the effects of decreased preload on RV systolic function in HD patients using echocardiographic parameters. They showed that RV Sa velocity was independent of preload, whereas TAPSE value was dependent [33]. Similarly, in our study, TAPSE was found to be lower in patients with HD and volume load compared to the control group. Unlike our study, RV functions were evaluated before and after HD, and TAPSE increased due to decreased volume load after HD. In our study, the control group consisted of healthy individuals. Karavelioglu et al. [34] reported that RV systolic and diastolic functions were impaired in HD patients without hypertension or diabetes mellitus. We obtained similar findings.

PH is common in patients with CRF because several studies based on the echocardiographic evaluation of SPAP have reported a prevalence of 30-60% [35]. Di Lullo et al. [36] reported that about 20% of a cohort of adult hemodialysis patients had impairment of right ventricular function, and low TAPSE values (<15 mm). Also, Momtaz et al. [37] confirmed the high incidence of pulmonary hypertension and subclinical RV dysfunction in HD patients. This was consistent with our study. Tassin series, which was carried out in prolonged HD, correctly determined the dry weight and removed the interdialytic fluid and salt sufficiently in each session, and the patients were found to live about 10 years longer than the patients who underwent standard HD for 12 hours per week. This series demonstrated the importance of accurate volume determination [38,39].

Limitations

One of the limitations of the study was the relatively small number of patients and the fact that it was single-centered. Another important limitation was that right heart catheterization was an invasive procedure for the functional evaluation of RV and RA and not performed due to lack of indication.

Conclusion

In this study, we demonstrated that TAPSE, which is an important indicator of right ventricular function, decreases with volume increase. It is also a less costly, non-invasive method that can be repeated and measured by echocardiography. We believe that it can be used together with other methods in calculating dry weight in ESRD patients receiving HD treatment.

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