Original article

Effects of hemodialysis on the left and right heart functions in patients with end-stage renal disease

Son dönem böbrek hastalarında hemodiyalizin sol ve sağ kalp fonksiyonları üzerine etkisi

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Abstract

Background: It is known that patients with chronic renal failure are at increased risk for morbidity and mortality. We aimed to assess the effects of hemodialysis on certain parameters used to evaluate left and right ventricular systolic and diastolic functions using conventional and tissue Doppler echocardiography in patients with end-stage renal insufficiency.

Methods: In this prospective observational study, 41 uremic patients were evaluated via echocardiography before and 60 minutes after hemodialysis. Systolic and diastolic functions of left ventricle (LV) and right ventricle (RV) were measured by two dimensional, M-Mode, conventional and tissue Doppler echocardiography.

Results: While a significant increase was observed in the mean heart rate after hemodialysis, the mean body weight, systolic and diastolic blood pressure values were significantly decreased (all p values< 0.01). Compared to before hemodialysis, mitral E/ mitral annulus septal E' and mitral E/ mitral annulus lateral E' did not change (p= 0.105 and p= 0.165), but significant alterations were determined in many of M-Mode, conventional and other tissue Doppler echocardiographic parameters after hemodialysis (all p values< 0.05 and < 0.01).

Conclusions: Mitral E/ septal E' and mitral E/ lateral E' did not change following hemodialysis and therefore are the best parameters to use to assess diastolic function in hemodialysis patients. Since the other conventional and traditional Doppler parameters vary with hemodialysis, these are not accurate measurements in these patients.

Keywords: Renal insufficiency, hemodialysis, pulsed Doppler echocardiography

Özet

Amaç: Kronik böbrek yetmezliği olan hastalarda morbidite ve mortalite riskinin arttığı bilinmektedir. Kronik böbrek yetmezliği olan hastalarda hemodiyalizin sol ve sağ ventrikül sistolik ve diyastolik fonksiyonları üzerine etkisini konvansiyonel ve doku Doppler ekokardiyografi ile değerlendirmeyi

amaçladık.
Materyal ve metod: Bu ileriye dönük gözlemsel çalışmada hemodiyaliz öncesi ve diyalizden 60 dakika sonra 41 üremik hasta ekokardiyografi ile değerlendirildi. İki boyutlu, M- Mode, konvansiyonel ve doku Doppler ekokardiyografi ile sol ve sağ ventrikülün sistolik ve diyastolik fonksiyonları ölçüldü.
Bulgular: Hemodiyaliz sonrası kalp hızı anlamlı olarak artarken ortalama vücut ağırlığı, sistolik ve diyastolik kan basınçları azaldı (hepsi için p<0.001). Hemodiyaliz öncesine kıyasla hemodiyaliz sonrasında mitral E/ mitral anulus septal E' ve mitral E/ mitral anulus lateral E' değerleri değişmedi (p= 0.105 ve p= 0.165), fakat M-mode, geleneksel ve diğer doku Doppler parametrelerinde anlamlı değişiklikler oldu (tüm p değerleri < 0.05 ve < 0.01).
Sonuçlar: Mitral E/ septal E' ve mitral E/ lateral E' değerleri dializ sonrası değişmez, bu nedenle hemodiyaliz hastalarında diyastolik fonksiyonları değerlendirmek için en iyi parametrelerdir. Konvansiyonel ve diğer doku Doppler parametreleri hemodiyaliz ile değiştiği için bu hastalarda doğru sonuçlar vermez.

Anahtar Kelimeler: Böbrek yetmezliği, hemodializ, atımlı Doppler ekokardiyografi

Introduction

End-stage renal insufficiency (ESRI) is defined as irreversible impairment of renal functions and includes patients requiring dialysis or transplantation for treatment (1). It is known that patients with chronic renal failure (CRF) are at increased risk for morbidity and mortality (2). Acute effects of hemodialysis (HD) on the cardiovascular system are well known (3,4). The leading cause of mortality has been reported to be sudden cardiac death in patients undergoing HD due to CRF. Hemodialysis is related to ventricular arrhythmias and dynamic electrocardiographic changes. Electrocardiographic and echocardiographic findings may vary in dialysis (5). Thus, the dialysis procedure has been hypothesized to have important effects on sudden cardiac death.

Left ventricular hypertrophy and diastolic heart failure are common among patients with ESRI. In such patients, volume overload is also observed before dialysis (6). Echocardiography plays an important role in the evaluation of cardiac functions in patients with ESRI (7, 8). It is known that conventional diastolic function parameters are affected by preload. Although it has been suggested that tissue Doppler parameters are not affected by preload, there are some studies suggesting the opposite, and time for optimal evaluation in such patients remains uncertain (8, 9).

In the present study, left and right ventricular systolic and diastolic functions were measured by conventional and tissue Doppler before and after HD, and the primary aim was to investigate whether or not these parameters are preload-dependent.

Methods

Study Population

The present prospective, observational study was conducted between August 2012 and September 2012. Forty-one patients, who received HD due to ESRI in the Hemodialysis Unit for longer than three months, were included in the study. Patients regularly received HD three times a week with each session lasting for four hours, The mean age of the 41 patients (23 males and 18 females) was 50 ± 7.3 years (range 34-65 years). The mean dialysis duration was 7.4 ± 2.6 years. Demographic, clinical and laboratory characteristics of the study patients are presented in Table 1. The patients were excluded from the study in the presence of the following conditions: atrial fibrillation, left or right bundle branch block, uncontrolled hypertension, New York Heart Association (NYHA) III-IV heart failure or ejection fraction (EF) less than 50%, moderate-severe valvular insufficiency, history of acute coronary syndrome or revascularization in the last 6 months, pericardial effusion or poor echogenicity. All patients underwent echocardiographic evaluation before and 60 minutes after HD treatment. The patients were informed about the study and their written informed consents were obtained; the study was conducted in accordance with the Declaration of Helsinki.

Echocardiography

Standard M-mode, 2-dimensional images and spectral and color flow Doppler recordings of all patients were obtained in left lateral decubitus position by Philips HD7 (Philips Medical Systems, Solingen, Germany) echocardiography device using a 3.5 MHz probe under the guidance of electrocardiography monitoring. Echocardiographic examination was performed before and one hour after dialysis. Patients were asked to lie in the left lateral decubitus position; the images were obtained during quiet expiration. M-mode measurements were performed based on the recommendations of the American Society of Echocardiography (10). Modified Simpson's method was used to measure left ventricle ejection fraction (LVEF) (11), and tricuspid annular plane systolic excursion (TAPSE) was used to assess right ventricle (RV) systolic function (12). For measuring diastolic functions of RV (12) and LV (13) the pulsed wave Doppler sample volume was placed between the tips of tricuspid or mitral leaflets, and then the inflow velocity pattern was recorded. Three consecutive beats were recorded for each parameter, and the average was calculated. From the apical 4-chamber view, peak early (E) and late (A) transmitral and transtricuspid velocities, Deceleration time (DT) of E wave, isovolumetric relaxation time (IVRT), and E/A ratio, which are among the indicators of conventional diastolic function, were measured. Isovolumetric contraction time (IVCT) and ejection time (ET) were also measured. MPI that reflects systolic and diastolic function of LV or RV was calculated using the following formula: IVCT + IVRT / ET. After activating the Tissue Doppler Imaging (TDI) function on the system, the septal and lateral mitral annular velocities, the anterior, inferior sites of left ventricular walls, and the tricuspid lateral annular velocity were recorded from the 2- and 4-chamber views. A 3.5 mm pulse wave Doppler sample volume was placed and TDI signals were recorded. The Nyquist limit was set to a velocity range between 15 cm/s and 20 cm/s by minimizing the gain and using low-filter settings.

Statistical Analysis

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL, USA) version 17.0. The Shapiro Wilks test was used for normality. Results were expressed as mean ± standard deviation and median (min-max). Parameters before and after HD were compared using paired sample t-test for homogeneously distributed variables, and the Wilcoxon signed-rank test was used for the non-homogeneously distributed variables. A p value <0.05 was considered statistically significant.

Results

Effects of Hemodialysis on Hemodynamic and Biochemical Parameters

A significant decrease in the mean body weight (76 [50 - 85] kg vs72.6 [47.5 – 81.7], $p<0.001$) of patients, which was indicative of a decrease in preload after HD; mean ultrafiltration volume was 2560 ± 1000 ml (1300-4500 ml). A significant increase was observed in the mean heart rate after HD, whereas significant decreases were noted in systolic and diastolic blood pressures. Urea and creatinine levels were also significantly decreased (Table 2).

Effects of Hemodialysis on M-Mode Echocardiographic Parameters

Significant decreases were observed in the left ventricular end-diastolic diameter, left ventricular end-systolic diameter and left atrial diameter after HD. There was a significant increase in the mean TAPSE value. No significant changes were observed in aortic root diameter, interventricular septum (IVS), posterior wall (PW) and LVEF (Table 3).

Effects of Hemodialysis on Conventional Doppler Echocardiographic Parameters

E peak, A peak and E/A ratio were significantly decreased whereas IVRT and deceleration time (DT) significantly increased**.** No significant changes were observed in IVCT and ejection time (ET) and LV MPI values (Table 4).

Tricuspid E, tricuspid A value and tricuspid E/A ratio were significantly decreased. No significant changes were observed in RV MPI values (Table 4).

Effect of Hemodialysis on Tissue Doppler Echocardiographic Parameters

On tissue Doppler imaging of the left ventricle, E' septal, A' septal, S' septal, E' septal/ A' septal, E' lateral, A' lateral, S' lateral, E' lateral/A' lateral, E' anterior, A' anterior, S' anterior, E' anterior/A' anterior and E' inferior, A' inferior, S' inferior, E' inferior/ A' inferior were found to be significantly decreased, whereas E/ E' septal and E/ E' lateral were not found to be significantly changed (Table 5).

Tissue Doppler imaging of the RV revealed that tricuspid lateral anulus E', tricuspid lateral anulus A', tricuspid lateral anulus S' and tricuspid lateral anulus E'/ tricuspid lateral anulus A' values were observed to be significantly decreased after HD (Table 6).

Discussion

Changes in echocardiographic parameters have been well documented in patients undergoing HD program (14). It has been reported that single-session HD improves systolic functions and that preload-dependence of diastolic variables are more prominent (15). A clearly defined understanding of the acute and long-term effects of HD on cardiac functions would be beneficial in terms of estimating and preventing future cardiovascular events. In their study, Hung et al. (16) demonstrated that HD-related volume reduction, which causes a reduction in preload, led to changes in heart size, volume, mass and hemodynamics. The present study demonstrated that aortic root, IVS, PW and LVEF were not affected by preload; however left ventricle and left atrium diameters were affected by preload in renal failure patients receiving dialysis. Our findings were similar with the findings of Hung et al (16).

TAPSE values greater than 2 cm indicate the normal right ventricle systolic functions (17). Taking into account TAPSE values, our study population consisted of patients with right ventricular systolic dysfunction due to volume overload, and after HD mean TAPSE values were increased similar to a previous study (18). We could potentially speculate HD reduces myocardial edema, removes uremic toxins from myocardium, and the right ventricle consequently contracts better and TAPSE improves.

Mitral and tricuspid flow parameters are used to evaluate left and right ventricular diastolic functions, respectively. Changes in preload should be taken into account when evaluating diastolic functions in patients receiving HD. Conventional Doppler echocardiography parameters are volume and preload-dependent, and play a limited role in determining diastolic dysfunction in such patients. In our study, significant decreases were observed in mitral and tricuspid flow E, A wave velocity and E/A ratio due to decreased volume caused by HD. The present study also demonstrated significant increases in DT, IVRT values after HD treatment due to preload reduction. These findings suggest that all conventional diastolic function parameters are pre-load dependent. Akkaya et al (18) evaluated the effects of HD on the RV functions and reported that tricuspid lateral annular systolic velocity and MPI values were preload-independent, whereas the conventional and tissue Doppler parameters of RV diastolic functions were preload-dependent. In addition, other groups have previously shown that conventional diastolic function parameters were preload dependent whereas TDI parameters were not preload dependent (19, 20).

Myocardial performance index is a reliably measures combined systolic and diastolic function of the left and right ventricle (21). RV MPI has the strong long-term prognostic importance compared to other right ventricular function parameters in a population of moderate heart failure (22) .While Akkaya et al. (18) and Ulucam et al. (23)determined that decreased preload due to HD affected neither right nor left ventricular MPI values, a study reported that MPI increases due to increased IVRT and decreased ET values after HD (24). The reason for these differences may be related to the degree of volume loss and changes in heart rate. In fact, a reduced preload leads to decreased IVCT and ET, yet increased IVRT, and consequently MPI does not change. We did not find any changes in the values of both the right and left ventricular MPI, as previously reported in some previous studies (18, 23).

There are some contradictions as to whether TDI parameters are preload-dependent or not. Some authors suggest that some TDI parameters such as E', A', S' and E'/A' were affected by preload reduction (15, 18, 25-29) yet other authors reported that these TDI parameters were not changed by preload (19, 20). Likewise, different results have been reported in about the relationship between E/E' and preload; some studies have reported no difference between E/E' values before and after dialysis (19, 28). Other studies have shown to reduce E/E' values after dialysis (20, 29). The reasons for these contradictions may be related to the degree of volume loss, changes in heart rate, the presence and degree of anemia and ventricular hypertrophy. Indeed, if more fluid is retracted during dialysis, diastolic function parameters could be more affected.

After HD by decreasing volume about 2800 ± 820 ml, Mendes et al. (28) found that septal and lateral E' and lateral E'/A' were decreased, lateral S' was increased whereas septal and lateral A', E/ septal E' and E/ lateral E' showed no change. In our study, mean ultrafiltration volume was 2560 ± 1000 ml. Drighil et al. (29) found that septal S', E', E'/A', lateral S', tricuspid lateral annulus E', E'/A' and mitral E/ lateral E' values were decreased, whereas lateral E', A', E'/A', septal A', tricuspid lateral annulus A' and mitral E/septal E' values showed no change. The authors state that left and right ventricular systolic and diastolic tissue Doppler velocities are dependent on the pre-load, lateral anulus is less affected by changes in preload. All tissue Doppler systolic and diastolic parameters except mitral E/ septal E' and mitral E/ lateral E' were decreased due to preload reduction in our study. Reduction of E' wave and E'/A' ratio can be explained by preload reduction caused by HD.

Reduction of A' and S' wave can be explained by Frank Starling law. According to the Frank Starling law, preload reduction leads to a reduction of heart contractions. S' wave is associated with ventricular contraction and A' wave is associated with atrial contraction. The amplitude of E', A' and S' wave decreases due to the combined effect of reduction of preload and Frank Starling law after hemodialysis. Mitral E/ septal E' or mitral E/ lateral E' ratio does not change after HD, because the E wave and E' wave decrease at the same rate. Based on these results we suggest that volume excess before hemodialysis may mask the real value of all the tissue Doppler systolic and diastolic parameters, whereas the real value of mitral E/ septal E' or mitral E/ lateral E' cannot masked.

The main limitation of the study was its size. It would be better to take measurements at 6 and 12 hours after HD treatment, however, the majority of this small study group did not accept reevaluation.

Conclusions

Hemodialysis alters many parameters used to evaluate left and right ventricular systolic and diastolic functions in ESRI patients. Particularly, conventional flow parameters, which are used to evaluate diastolic dysfunction, and tissue Doppler parameters are influenced by preload. Mitral E/ septal E' and mitral E/ lateral E' were useful independent volume parameters for the assessment of diastolic function.

Table 1: Baseline demographic and laboratory characteristics of the study patients (n=41)

Variables	Values
Age, years	50 ± 7.3
Male/Female, n	23/18
Height, cm	164 ± 4.3
Weight, kg	71.7 ± 8.65
Systolic BP, mmHg	143 ± 18.6
Diastolic BP, mmHg	89 ± 7.6
Dialysis duration, years	7.4 ± 2.6
Diabetes Mellitus, n (%)	19 (39.6)
Hypertension, n (%)	34 (70.8)
Hemoglobin, g/dL	9.3 ± 1.3
Glucose, mg/dL	98.6 ± 26.3
Serum urea, mg/dL	116.8 ± 22.8
Serum creatinine, mg/dL	8.9 ± 1.6

BP: blood pressure. Data are presented as mean ± standard deviation, % or number, where appropriate.

Table 2: Laboratory characteristics of the study patients (n=41) before and after hemodialysis

Variables	Before HD	After HD	p value
Weight, kg	76 (50 - 85)	72.6 (47.5 – 81.7)	<0.001
Systolic BP, mmHg	143 ± 18.6	123.5 ± 14.3	<0.001
Diastolic BP, mmHg	89 ± 7.6	81.4 ± 4.4	<0.001
Heart rate, beats/minute	81.3 ± 6.6	89.5 ± 9.4	<0.001
Serum urea, mg/dL	116.8 ± 22.8	72.5± 8.3	<0.001
Serum creatinine, mg/dL	8.9 ± 1.7	5.6 ± 1.6	<0.001

HD: hemodialysis, BP: blood pressure. Data are presented as mean ± standard deviation or median (interquartile range)

Table 3: M-mode indices before and after hemodialysis (n=41)

Variables	Before HD	After HD	p value
LVDD, mm	47.4 ± 3.8	46.5 ± 3.2	0.031
LVSD, mm	30.4 ± 1.8	27.8 ± 1.9	0.032
IVS, mm	14.2 ± 1.5	14.2 ± 1.4	0.734
PW, mm	13.5 ± 1.2	13.6 ± 1.2	0.534
EF, %	65.9 ± 3.2	66.2 ± 3.1	0.223
Left atrium, mm	37.9 ± 5.2	36.3 ± 5.3	0.035
Aortic root, mm	32.7 ± 3.6	32.2 ± 3.4	0.512
TAPSE, cm	1.9 (1.6 – 2.3)	2.1 (1.8 – 2.4)	0.003

Data are presented as mean±standard deviation or median (interquartile range). HD: hemodialysis; SD: standard deviation; LVDD: left ventricular diastolic diameter; LVSD: left ventricular systolic diameter; IVS: interventricular septum; PW: posterior wall; EF: ejection fraction; TAPSE: tricuspid annular plane systolic exurcion

Table 4: Pulsed-Doppler indices before and after hemodialysis (n= 41)

Variables	Before HD	After HD	P value
E peak, cm/s	95 (47 - 123)	82 (45 -105)	0.001
A peak, cm/s	97 ± 17.9	91 ± 14.7	0.042
E/A ratio	0.84 (0.6 – 1.8)	0.79 (0.6 - 1.2)	0.001
Deceleration time, ms	168.4 ± 38.2	183.8 ± 29.3	0.042
IVRT, ms	79 (70 - 88)	85 (74 - 101)	0.041
IVCT, ms	47 (26 - 61)	47 (31 - 67)	0.781
Ejection time, ms	290 ± 24.7	288 ± 30.8	0.785
LV MPI	0.44 ± 0.06	0.45 ± 0.07	0.077
E Tricuspid, cm/s	57 (43 - 85)	45 (35 - 57)	0.003
A Tricuspid, cm/s	68 (60 - 78)	59 (50 - 74)	0.025
E/A Tricuspid	0.88 (0.6 - 1.3)	0.80 (0.5 – 0.9)	0.027

Table 5: Tissue Doppler measurements of left ventricle before and after hemodialysis (n=41)

Variables	Before HD	After HD	P value
E’ septal, cm/s	8 (7 – 13)	7 (5 - 11)	0.001
A’ septal, cm/s	10 (8 - 14)	8 (6 - 13)	0.001
S’ septal, cm/s	8 (5 - 18)	7(5 - 11)	0.002
E’ septal/ A’ septal	0.88 (0.73 – 1.13)	0.80 (0.63 - 1.14)	0.001
E/ E’ septal	7.8 (4.7 - 15.4)	8.1 (5.5 – 13.4)	0.756
E’ lateral, cm/s	9(6 - 12)	7(6 - 8)	0.001
A’ lateral, cm/s	9.6 ± 3.2	9.2 ± 2.1	0.047
S’ lateral, cm/s	8 (6 – 11)	7 (5 – 8)	0.001
E’ lateral/ A’ lateral	0.87 (0.64 – 1.25)	0.77 (0.5 – 1.14)	0.001
E/ E’ lateral	8 (5 – 13.7)	8.1 (6.2 – 13.6)	0.861
E’ anterior, cm/s	8 (7 - 13)	6.5 (5.5 - 8)	0.001
A’ anterior, cm/s	9.6 (7 - 13)	8.5 (6 - 10)	0.001
S’ anterior, cm/s	8 (6 - 18)	7.5 (6 - 11)	0.032
E’ anterior/ A’ anterior	0.9 ± 0.17	0.8 ± 0.12	0.004
E’ inferior, cm/s	8 (5 - 19)	7 (5 - 11)	0.001
A’ inferior, cm/s	9.5 (7 - 15)	9 (7 - 12)	0.045
S’ inferior, cm/s	9 (7 - 13)	8 (6 - 12)	0.003
E’ inferior/ A’ inferior	0.87 (0.5 – 1.6)	0.77 (0.6 - 1.4)	0.048

Data are presented as mean±standard deviation or median (interquartile range), HD: hemodialysis.

Table 6: Tissue Doppler measurements of right ventricle before and after hemodialysis (n=41)

Variables	Before HD	After HD	P value
Tric. lateral annulus E', cm/s	10 (7 - 15)	8 (6 - 11)	0.001
Tric. lateral annulus A', cm/s	12 (8 - 17)	10 (7 - 14)	0.001
Tric. lateral annulus S', cm/s	13 (8 - 17)	10 (7 -17)	0.001
Tric. lateral annulus E'/A'	0.85(0.67 – 1.13)	0.80 (0.5 - 1)	0.006

Data are presented as mean±standard deviation or median (interquartile range) HD: hemodialysis; Tric.: tricuspid

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