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The relation between body fluid composition and echocardiographic tissue Doppler measurements in patients with end-stage renal disease

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Abstract

Aim The relationship between body fluid composition measurements and echocardiographic tissue Doppler measurements before and after hemodialysis (HD) in end-stage renal disease is investigated.

Materials and methods BCM (BCM-Fresenius Medical Care) Body Composition Monitor was used to measure the fluid status and body composition of patients by BIA method. TDE was performed before and after HD and the measurements were recorded.

Results The mean age of the 72 patients was 53.7 ± 17.2 years. There was a significant decrease in over hydration (OH) status, total body fluid (TBW), extracellular body fluid (ECW), intracellular body fluid (ICW), ECW/ICW ratio in patients after HD ($p < 0.001$, p0.001, p0.001, p0,001). A significant decrease in lateral, septal and tricuspid E' measurements and in E'/A' ratio was seen after HD (p: 0.012, p: 0.001, $p < 0.001$, p: 0.002, p0.001, p0,001). There was a significant difference in A' measurements from septal annulus in patients before and after HD (p: 0.001). A significant increase was observed in isovolemic contraction volume (IVCV) measurements from lateral, septal and tricuspid annulus in patients after HD ($p < 0.001$, p0.001, p: 0.012). A correlation was determined between the differences of lateral and tricuspid valve E' in patients before and after HD and the differences of ECW in patients before and after HD (p: 0.007 r: 0.401, p: 0.017 r: 0.358).

Conclusion In this study; a correlation was determined between the acute decrease in OH amount and alteration in echocardiographic tissue Doppler parameters in patients after HD.

Keywords Hemodialysis · Bioimpedance analysis measurement · Tissue Doppler measurements · Over hydration

Introduction

End-stage renal disease is a notably important health problem affecting the adult population with an increasing prevalence. Although end-stage renal disease itself is a cause of mortality, also accompanying organ damages contribute to mortality. Fluid balance is considered as an important component of treatment in hemodialysis (HD) patients [1]. However, the development of chronic hypervolemia may lead to hypertension, increased arterial stiffness, chronic heart failure (CHF), left ventricular hypertrophy (LVH), increased morbidity and mortality, and other adverse consequences [2, 3]. On the other hand, dehydration may cause hypotension, cramps, dizziness, etc. [4]. As chronic hypervolemia is the cause of hypertension in 80% of HD patients and cardiovascular complications are one of the main causes of death, correct volume control may lead to reduction of blood pressure, LVH regression, and improved survival in these patients [5].

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There is no simple and easy method for the determination of dry weight. Dry weight is determined by a trial and error method that prevents blood pressure control and causes some complications during dialysis in most of the dialysis centres [6]. Clinically, dry weight is the lowest weight that the patient can tolerate after dialysis without any clear signs of hypotension or overload [4]. As well as the symptoms of the patient's, edema, jugular venous fullness, and blood pressure also biochemical markers (natriuretic peptide), blood volume monitor (BVM), inferior vena cava diameter measurement, and bioimpedance applications contribute to the determination of dry weight [7]. One of the application areas of bioimpedance analysis is the determination of body composition and hydration properties. The Body Composition Monitor (BCM) is a recently developed device which provides a quantitative measure of hydration status for the determination of volume status in patients receiving renal replacement therapy [1].

Echocardiography is a preferred imaging modality due to the accuracy, convenience, safety and cost. Aberration of isovolumic left ventricular relaxation time (IVRT), ratio of mitral filling velocities (E/A) and early mitral filling velocity curve (DT) are sensitive but non-specific findings of diastolic functions in the screening of detoriated left ventricule functions by echocardiography. Since echocardiographic tissue Doppler findings are more independent of preload and afterload, they are more reliable for the demonstration of diastolic functions. Therefore, it is used more frequently to show diastolic functions. Peak systolic contraction velocity and early diastolic relaxation velocity in tissue Doppler measurements recorded from septal or lateral mitral annulus are considered as sensitive measurements for the determination of left ventricular systolic and diastolic functions. It is known that ratio of early mitral flow velocity to early diastolic relaxation velocity is a very good indicator of left ventricular filling pressure. There are various studies on these subjects. In one of these studies, it was stated that the right and left ventricular systolic and diastolic tissue Doppler measurements were preload dependent [8]. Also, tissue Doppler measurements which were performed to demonstrate right ventricular dysfunction were found high before HD [9]. In another study, it was stated that, over fluid load (OH)/extracellular water (ECW) ratio measured by bioimpedance spectroscopy was the main indicator of left atrium diameter, left ventricular mass and ejection fraction as the bioimpedance spectroscopy (such as Body composition monitor) is a reliable method for determining the volume status of HD patients. [10]. Echocardiographic measurements show high correlation with hydration status in HD patients [11].

The aim of this study is to show the relationship between body fluid composition and echocardiographic tissue Doppler measurements in end-stage renal disease.

Materials and methods

Patients

96 patients who have been in dialysis program at Hemodialysis Unit were assessed in the study. After evaluating the patients according to exclusion criteria, 72 HD patients who underwent systemic bicarbonate HD for at least 2 months, 3 times a week for 4 h were included in the study. The patients were informed about the study, a written, signed consent form was obtained and included in the study on a voluntary basis. Patients younger than 18 years and older than 85 years were excluded from the study. Patients with electronic medical device implant, metal artificial joint, any limb amputation, class 3–4 heart failure, severe heart valve pathology, pericardial disease, acute myocardial ischemia, atrial fibrillation, active infection, pregnancy status were not included in the study.

Blood pressure was measured in the sitting position after resting for at least 10 min. Height (cm) and weight (kg) of the patients were measured. Body mass indexes (BMI) (kg/m^2) were calculated. Systolic and diastolic blood pressure measurements were recorded.

This study was planned as prospective and approved by Gazi University Medical Faculty Ethical Committee.

Bioimpedance analysis measurement

BCM (BCM-Fresenius Medical Care) Body Composition Monitor was used to measure the fluid status and body composition of patients by BIA method. Body fluid composition measurements of the patient were performed after 10–15 min resting, in supine position, by placing total of 4 electrodes on dorsal faces of the hands and feet, at 1 cm proximal of wrist and metacarpophalangeal, metatarsophalangeal, and metatarsophalangeal joints of the extremities which have no fistula/catheter. These electrodes were connected to the device. After entering the age, weight and height data for each patient, measurements were completed over 1–4 min. Measurements were performed before and 30 min after HD. Patients' over hydration (OH), total body fluid (TBW), extracellular body fluid (ECW), intracellular body fluid (ICW), extracellular/intracellular body fluid ratio (ECW/ICW), body mass index (BMI), lean tissue index (LTI), fat tissue index (FTI), lean tissue mass (LTM), fat tissue mass (ATM) values were measured.

Echocardiographic measurements

All measurements were performed by echocardiography (2.5 MHz transducer, Vivid 7 Dimension) device by the

same cardiologist who did not know BIA results before and after 30 min rest subsequent to HD. Left ventricular diastolic and end-systolic diameter (mm), left ventricular diastolic and end-systolic volume (mL), septum thickness (mm), posterior wall thickness (mm), left atrium diameter (mm), right ventricular end-diastolic diameter (mm), right artium end-diastolic diameter (mm), E ', A', E '/A', peak systolic velocity (PSV, cm/s), isovolemic contraction volume (IVCV, cm/s), isovolemic contraction time (IVCT, ms), isovolemic relaxation volume (IVRV, cm/s), isovolumic relaxation time (IVRT, ms), ejection time (ET, ms) measurements were recorded.

Statistical method

Statistical analyses were performed using IBM SPSS for Windows Version 21.0 package program. Numerical variables were represented as mean ± standard deviation or median [minimum–maximum] values. Categorical variables were indicated by number and percentage. Normality of numerical variables was examined by Shapiro Wilks test and homogeneity of variance was examined by Levene test. Whether there are differences between two independent groups in terms of numerical variables were determined with Mann–Whitney U test as parametric test assumptions were not provided. More than two groups were compared with Kruskal–Wallis test. In case of differences, pairwise comparisons were made with Siegel Castellan test. Differences between numerical values before and after HD were examined by t test if parametric test assumptions were provided, and by Wilcoxon test if parametric test assumptions were not provided in dependent groups. Comparisons of categorical variables before and after HD were performed by McNemar test. The significance level was accepted as $p < 0.05$.

Results

The study included 72 patients with a mean age of 53.7 ± 17.2 years in the chronic HD program. 27 female (37.5%) and 45 male (62.5%) patients were included in the patient group. Diabetes mellitus was the most common cause (27.8%) followed by hypertension (25%). Left ventricular end-diastolic diameter was measured as 46.05 ± 4.81 mm and the end-systolic diameter as 29.48 ± 4.03 mm with echocardiography in patients before HD. Left ventricular end-diastolic volume was detected as 98.27 ± 24.70 mL, and the end-systolic volume was detected as 34.15 ± 11.96 mL. Septum thickness was measured as 1.26 ± 0.19 mm and left atrium diameter was measured as 37.65 ± 6.56 mm. Demographic characteristics and echocardiographic measurements of patients before HD are shown in Table 1.

Table 1 Demographic characteristics of patients and echocardiographic measurements before HD

	Patients (*n*: 72)
Age (years)	53.7 ± 17.2
Gender	
Female, *n* (%)	27 (37.5%)
Male, *n* (%)	45 (62.5%)
Body mass index (BMI), kg/m^2	26.45 ± 5.88
Hemodialysis duration (month), median	44 (2–228)
Hemodialysis entry site	
Fistula, *n* (%)	59 (81.9%)
Catheter, *n* (%)	13 (18.1%)
Cause of chronic kidney disease	
Diabetic Nephropathy, *n* (%)	20 (27.8%)
Hypertensive Nephropathy, *n* (%)	18 (25%)
Glomerulonephritis, *n* (%)	8 (11.1%)
Pyelonephritis, *n* (%)	3 (4.2%)
Multiple Myeloma, *n* (%)	3 (4.2%)
Vasculitis, *n* (%)	2 (2.7%)
Other causes, *n* (%)	18 (25%)
Left ventricular end-diastolic diameter (mm)	46.05 ± 4.81
Left ventricular end-systolic diameter (mm)	29.48 ± 4.03
Left ventricular end-diastolic volume (mL)	98.27 ± 24.70
Left ventricular end-systolic volume (mL)	34.15 ± 11.96
Septum thickness (mm)	1.26 ± 0.19
Posterior wall thickness (mm)	1,11 ± 0.20
Diameter of left atrium (mm)	37.65 ± 6.56
Right ventricular end-diastolic diameter (mm)	35.06 ± 4.43
Right atrium end-diastolic diameter (mm)	38.65 ± 38.65

Patients' systolic blood pressure was found as 131.67 ± 15.6 mmHg before HD and as 116.73 ± 19.68 mmHg after hemodialysis and the difference was significant ($p < 0.001$). Diastolic blood pressure was determined as 78.96 ± 9.74 mmHg before HD and as 68.4 ± 12.24 mmHg after HD and the decrease was significant ($p < 0.001$). The amount of OH before HD was found to be 1.17 ± 1.55 L and the decrease in OH after HD was significant ($p < 0.001$). There was a significant decrease in TBW measurements after HD ($p < 0.001$). ECW was measured as 16.25 ± 3.43 L before HD and 14.17 ± 3.09 L after HD and the decrease was significant ($p < 0.001$). While there was no significant difference in ICW measurements, the ECW/ICW ratio which was measured before and after HD was compared and the decrease after HD was found significant ($p < 0.001$). The comparison of BCM measurement before and after HD is shown in Table 2.

A significant decrease was observed in lateral, septal and tricuspid E' measurements after HD in echocardiographic tissue Doppler measurements of patients (respectively, *p*: 0.012, *p*: 0.001, $p < 0.001$). There was a significant

Table 2 BCM measurements of patients before and after HD

	Before HD	After HD	*p*
OH (L)	1.17 ± 1.55	− 0.99 ± 1.60	< 0.001
TBW (L)	34.51 ± 7.24	32.4 ± 6.6	< 0.001
ECW (L)	16.25 ± 3.43	14.17 ± 3.09	< 0.001
ICW (L)	18.25 ± 4.10	18.24 ± 4.02	0.937
ECW/ICW	0.89 ± 0.1	0.78 ± 0.12	< 0.001
LTI (kg/m^2)	13.49 ± 2.74	13.56 ± 2.81	0.646
FTI (kg/m^2)	12.2 ± 6.24	12.11 ± 6.25	0.10
LTM (kg)	36.79 ± 9.31	37.05 ± 9.43	0.590
FAT (kg)	24.49 ± 12.36	24.1 ± 12.7	0.190
ATM (kg)	33.29 ± 16.74	32.77 ± 17.29	0.214

OH, overhydration; TBW, total body fluid; ECW, extracellular body fluid; ICW, intracellular body fluid; ECW/ICW, extracellular/intracellular body fluid ratio; LTI, lean tissue index; FTI, fat tissue index; LTM, lean tissue mass; ATM, fat tissue mass

difference in A' measurements before and after HD in septal measurement (*p*: 0.001). Lateral, septal and tricuspid E '/A' ratios of the patients were significantly different before and after HD ($p = 0.002$, $p < 0.001$, $p = 0.001$, respectively). PSV lateral, septal and tricuspid measurements were found significantly higher in patients after HD ($p < 0.001$, p0.001, *p*: 0.018, respectively). A significant increase was observed in IVCV lateral, septal and tricuspid measurements with echocardiographic Doppler in patients after HD ($p < 0.001$, p0.001, *p*: 0.012, respectively). A significant decrease was observed in IVCT measurements, in lateral measurement ($p < 0.001$). Septal measurement was found to be significant in IVRV before and after HD (*p*: 0.035). A significant decrease was observed in all three measurements in ET measurement ($p < 0.001$, p0.001, p0.001, respectively). Echocardiographic tissue Doppler measurements of patients before and after HD are shown in Table 3.

Correlation was determined between the differences of echocardiographic tissue Doppler lateral and tricuspid valve E' before and after HD and the differences of ECW before and after HD in correlation analysis of septal, lateral and tricuspid valve echocardiographic tissue Doppler E', A' and E'/A' ratio differences in patients before and after HD and of TBW, ECW, ICW differences which were measured by bioimpedance analysis method (*p*: 0.007 *r*: 0.401, *p*: 0.017 *r*: 0.358, respectively) (Table 4).

Table 3 Echocardiographic tissue Doppler measurements before and after HD

	Before HD	After HD	*p*
E' (cm/s)			
Lateral	0.09 ± 0.03	0.08 ± 0.02	0.012
Septal	0.06 ± 0.02	0.05 ± 0.02	0.001
Tricuspid	0.10 ± 0.03	0.07 ± 0.03	< 0.001
A' (cm/s)			
Lateral	0.08 ± 0.02	0.08 ± 0.02	0.122
Septal	0.07 ± 0.02	0.08 ± 0.02	0.001
Tricuspid	0.13 ± 0.06	0.14 ± 0.04	0.133
E'/A'			
Lateral	1.21 ± 0.64	0.97 ± 0.47	0.002
Septal	0.93 ± 0.38	0.74 ± 0.33	< 0.001
Tricuspid	0.85 ± 0.45	0.57 ± 0.29	< 0.001
PSV (cm/s)			
Lateral	0.07 ± 0.02	0.08 ± 0.00	< 0.001
Septal	0.06 ± 0.01	0.08 ± 0.07	< 0.001
Tricuspid	0.12 ± 0.02	0.11 ± 0.04	0.018
IVCV (cm/s)			
Lateral	0.04 ± 0.02	0.07 ± 0.03	< 0.001
Septal	0.04 ± 0.01	0.07 ± 0.03	< 0.001
Tricuspid	0.09 ± 0.03	0.10 ± 0.04	0.012
IVCT (ms)			
Lateral	106.0 ± 40.09	83.23 ± 25.25	< 0.001
Septal	85.29 ± 19.47	80.75 ± 21.38	0.079
Tricuspid	88.56 ± 23.28	85.27 ± 21.66	0.225
IVRV (cm/s)			
Lateral	0.03 ± 0.01	0.03 ± 0.01	0.099
Septal	0.03 ± 0.01	0.03 ± 0.01	0.035
Tricuspid	0.04 ± 0.01	0.03 ± 0.01	0.084
IVRT (ms)			
Lateral	92.62 ± 34.62	95.68 ± 38.66	0.901
Septal	100.40 ± 25.27	97.01 ± 31.62	0.437
Tricuspid	97.04 ± 37.93	97.69 ± 37.08	0.902
ET (ms)			
Lateral	262.5833 ± 46.06	219.43 ± 46.13	< 0.001
Septal	277.8056 ± 32.73	228.11 ± 41.54	< 0.001
Tricuspid	270.59 ± 45.2	221.04 ± 45.96	< 0.001

PSV, peak systolic velocity; IVCV, isovolemic contraction volume; IVCT, isovolemic contraction time; IVRV, isovolemic relaxation volume; IVRT, isovolumic relaxation time; ET, ejection time

Discussion

In this study, a correlation was determined between the acute decrease in OH amount and alteration in echocardiographic tissue Doppler parameters in patients after HD. As a result of the decreased amount of hypervolemia and the alteration of tissue Doppler parameters, the preload dependence of systolic and diastolic functions and the effect of acute change in hypervolemia on cardiac functions were demonstrated. In consideration of this study, we emphasize the importance of bioimpedance methods for the detection of hypervolemia and the subsequent planning of the treatment.

The most common renal replacement therapy is HD in all around the world and in our country. One of the common problems in HD patients is that their dry weight cannot be calculated clearly. As a result, chronic hypervolemia are

Table 4 Comparison of echocardiographic tissue Doppler E', A' and E'/A' ratio differences in patients before and after HD and TBW, ECW, ICW differences

	TBW difference (L)		ECW difference (L)		ICW difference (L)	
	r	*p*	*r*	*p*	*r*	*p*
E' (cm/s)						
Lateral	0.247	0.106	0.401	0.007	0.030	0.848
Septal	−0.027	0.861	0.174	0.260	−0.199	0.195
Tricuspid	0.165	0.284	0.358	0.017	−0.076	0.622
A' (cm/s)						
Lateral	−0.046	0.765	0.154	0.317	−0.211	0.169
Septal	−0.109	0.481	0.080	0.606	−0.226	0.140
Tricuspid	0.044	0.776	0.100	0.517	−0.006	0.969
E'/A' (cm/s)						
Lateral	0.208	0.176	0.133	0.388	0.247	0.107
Septal	−0.074	0.634	−0.022	0.889	−0.100	0.519
Tricuspid	−0.019	0.903	0.179	0.244	−0.204	0.184

observed due to inadequate ultrafiltration [12, 13]. This leads to an increase in blood pressure, which is an independent risk factor for cardiovascular disease in patients. Bioimpedance analysis method is recommended for the evaluation of dry weight in recent years. The safety of bioimpedance analysis method has been investigated in many studies [12, 14, 15]. In a comparative study conducted by Wizemann et al. 200 subjects (50 healthy, 50 pre-dialysis, 50 chronic HD and 50 transplant patients) were evaluated with bioimpedance analysis to determine the hypervolemia and significant hypervolemia was found in pre-dialysis and chronic hemodialysis patients when compared to other groups (normal healthy individuals and transplant patients) [16]. Bioimpedance analysis methods have been reported as useful for monitoring fluid movements in body fluid compartments by Cin et al. [17]. In our study, the amount of OH was determined as 1.17 ± 1.55 in patients before HD. There was a significant decrease in the amount of OH when before and after HD were compared. A significant decrease was observed in TBW, ECW, ECW/ICW measurements in patients after HD. In a study by Juan García et al. 117 patients (65 HD patients, 52 peritoneal dialysis patients) were examined. Bioimpedance analysis measurements of HD patients were performed before and after HD. While OH, TBW, ECW, ECW/ICW changes were found to be significant, there was no significant change in ICW. No significant difference was found in fat and muscle mass measurements [11].

Global left ventricular function consists a combination of ejection (systolic function) and ventricular filling (diastolic function). Conventional echocardiography provides significant information about systolic functions, whereas Doppler echocardiography methods are used more frequently in the analysis of diastolic functions. Most conventional echocardiography parameters are preload dependent [18]. It is suggested that, echocardiographic tissue Doppler methods are going to contribute to the solution of many clinical problems, where conventional echocardiography methods are inadequate, such as objective determination of left ventricular regional systolic function, viability and evaluation of diastolic functions by improving over time and by the development of colour tissue Doppler method [19]. Early and late diastolic mitral velocity pattern, isovolumetric relaxation time, and isovolumetric contraction time reflect the diastolic ventricular performance. Both systolic and diastolic Doppler intervals are variables that are affected by heart filling and heart rate [19]. Although there are some studies reported that the echocardiographic tissue Doppler measurements are preload dependent [20, 21], there are some studies stated the opposite [22, 23]. The reason for these different results was attributed to the heterogeneity of the study groups. Hence, Drighil et al. attributed this inconsistency to the different amount of ultrafiltration performed in HD [8]. Nagueh et al. showed that echocardiographic tissue Doppler measurements were preload dependent in patients with normal cardiac relaxation, whereas tissue Doppler measurements were not preload dependent in patients with abnormal relaxation [24].

In our study, mitral inflow measurements of patients before and after HD were examined. Although a significant decrease in peak E value was observed in patients after HD, no significant change in peak A value was observed. There was a significant difference in E/A ratio in patients before and after HD. Although no significant difference was determined in IVRT measurements in patients before and after HD, a significant decrease was found in IVCT measurements. When MPI measurements were compared in patients before and after HD, the increase observed after HD was significant. In the study of Abdenasser et al. peak mitral E and A was measured with echocardiographic tissue Doppler in 17 HD patients and a significant decrease was found after HD. Peak E and A measurements are reported as preload dependent. An increase in intravascular volume before HD

results with an increase in preload which masks early diastolic dysfunction. It was interpreted as HD causes acute preload decrease, peak early volume rate decrease and facilitate the occurrence of delayed relaxation [8]. In line with these comments, peak E, E/A and IVCT were interpreted as preload dependent in our study. In other words, our study supports the preload dependence of diastolic functions.

A significant difference was found between lateral, septal and tricuspid E' measurements in echocardiographic tissue Doppler measurements in patients before and after HD in our study. While a significant difference was found in A' measurements in patients before and after HD in septal measurement, no significant difference was seen in lateral and tricuspid measurements. A significant difference was determined in lateral, septal and tricuspid E'/A' ratios when the measurements performed before and after HD were compared. In the study performed by Abdenasser et al. though the tricuspid and septal echocardiographic tissue Doppler E' measurements were found to be significant, there was no significant difference was seen in A' measurements in all three areas. E'/A' ratio was found significant in lateral, tricuspid and septal measurements. It was interpreted as E', E'/A' measurements were preload dependent in septal and tricuspid measurements. No significant difference was found in the lateral measurements; however, a significant difference was observed in the lateral measurements in patients with over ultra-filtrated with HD. Therefore, it was interpreted as also lateral measurements are preload dependent [8]. In the study performed by Anna et al. 45 HD patients were examined and they were evaluated with echocardiography before and after HD. E', lateral, septal and tricuspid measurements was found significant, but no significance was observed in A' in echocardiographic tissue Doppler measurements [25]. In consideration of these studies, it was interpreted as E', A' and E'/A' ratio are preload dependent. These acute changes in OH by HD clearly demonstrate the effect of hypervolemia on diastolic functions.

Myocardial performance index (MPI) is a non-invasive, important and reliable parameter for the assessment of global systolic and diastolic functions. Ozdemir et al. have reported that MPI measured by echocardiographic tissue Doppler method was not affected by preload and heart rate variability [26]. In our study, a significant increase was observed in MPI mitral inflow measurements after HD and this supports the preload dependence of MPI. The increase in MPI after HD can be interpreted as an indication of acute improvement in systolic and diastolic functions due to the decrease in volume load.

A correlation between lateral and tricuspid valve E' measurements and ECW difference was determined when the difference of septal, lateral and tricuspid valve echocardiographic tissue Doppler E', A' and E'/A' ratio of the patients before and after HD, and the difference of TBW, ECW, ICW before and after HD were examined. A study by Anna et al. showed that E' tricuspid and septal echocardiographic tissue Doppler measurements were correlated with OH amounts after HD [25]. It is the only study in which echocardiographic tissue Doppler and bioimpedance analysis method measurements are evaluated together and their correlation is examined. In line with the hypothesis of the study, it was shown that HD patients cannot be evaluated by echocardiography on every HD day, but dry weight can be determined by BCM which is a simpler method.

It is clear that reduction in over hydration is critical for the control of cardiovascular complications in HD patients. Therefore, easy applicable methods are needed for accurate ECW measurement [27]. In the study performed by Spiegel et al. ECW measurements of patients who has been achieved the clinically ideal dry weight were made by bioimpedance analysis methods and it was found that 50% of the patients had volume excess. This observation shows that HD patients cannot achieve to physiological ECW, and therefore, there is in need of other methods to determine the volume status [28]. Although biochemical markers such as ANP, BNP and cGMP can be auxiliary methods in terms of showing the volume load, their routine clinical use is limited because of the restriction of their use in cases such as congestive heart failure and valvular heart diseases and the high cost. Inferior vena cava measurement for hypervolemia is associated with large variations and operator-related errors [1]. No significant difference was detected between TBW, which was examined by bioimpedance analysis method and the gold standard D_2O [29].

The limited number of patients can be stated as the limitation of the study. Large-scale studies on this subject will be instructive. Other limiting factors are the lack of advanced echocardiographic methods, the presence of HD input and output data, the absence of baseline data, and the absence of volume load markers such as pro-BNP.

Conclusion

Left ventricular dysfunction is attributed to many reasons in HD patients. Uremia, left ventricular pressure increase and excessive volume overload have the most important role in this situation. Left ventricular hypertrophy develops as a result of hemodynamic changes and hypertrophy helps to maintain constant wall tension due to increased heart workload. This condition in the myocardium results with irreversible changes leading to myocardial fibrosis, myocyte hypertrophy and myocyte death. These changes presented as systolic insufficiency and diastolic dysfunction in clinic. Early diagnosis and treatment of these risk factors are vital to break this vicious cycle which hypervolemia has a prominent contribution. As we have demonstrated in our study,

tissue Doppler may be a superior method to observe acute changes in systolic and diastolic functions. In addition, as we have shown in our study, the correlation between echocardiographic tissue Doppler and bioimpedance measurements emphasizes the importance of bioimpedance methods for determination of hypervolemia and planning the treatment of patients. Therefore, we think that bioimpedance methods should be used more frequently in terms of practical measurement of hypervolemia, which has an important role in cardiac mortality in HD patients.

Authors' contributions All authors whose names appear on the submission. Made substantial contributions to the conception or design of the work; Drafted the work or revised it critically for important intellectual content; Approved the version to be published; and Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Compliance with ethical standards

Conflict of interest There is no Grants, financial support or conflict of interest for this article.

References

1. Jaeger JQ, Mehta RL (1999) Assessment of dry weight in hemodialysis: an overview. J Am Soc Nephrol 10(2):392–403
2. Voroneanu L et al (2010) The relationship between chronic volume overload and elevated blood pressure in hemodialysis patients: use of bioimpedance provides a different perspective from echocardiography and biomarker methodologies. Int Urol Nephrol 42(3):789–797
3. Chan C et al (2009) Combining near-subject absolute and relative measures of longitudinal hydration in hemodialysis. Clin J Am Soc Nephrol 4(11):1791–1798
4. Daugirdas JT, Blake PG, Ing TS (2007) Handbook of dialysis, vol 236. Lippincott Williams & Wilkins, Philadelphia
5. Charra B, Chazot C (2003) Volume control, blood pressure and cardiovascular function: lessons from hemodialysis treatment. Nephron 93(4):P94
6. Codognotto M et al (2007) Renal dysfunction is a confounder for plasma natriuretic peptides in detecting heart dysfunction in uremic and idiopathic dilated cardiomyopathies. Clin Chem 53(12):2097–2104
7. Sabaghian T, Hajibaratali B, Samavat S (2016) Which echocardiographic parameter is a better marker of volume status in hemodialysis patients? Ren Fail 38(10):1659–1664
8. Drighil A et al (2008) Haemodialysis: effects of acute decrease in preload on tissue Doppler imaging indices of systolic and diastolic function of the left and right ventricles. Eur J Echocardiography 9(4):530–535
9. Said K et al (2012) Ventricular function in patients with end-stage renal disease starting dialysis therapy: a tissue doppler imaging study. Echocardiography 29(9):1054–1059
10. HÜR E, et al. Bioimpedance spectroscopy for the detection of hypervolemia in hemodialysis patients. https://doi.org/10.5262/tndt.2011.1003.05
11. Juan García I et al (2012) Echocardiographic impact of hydration status in dialysis patients. Nefrología (English Edition) 32(1):94–102
12. Chen Y-C et al (2002) Adjusting dry weight by extracellular volume and body composition in hemodialysis patients. Nephron 92(1):91–96
13. Rahman M et al (2000) Interdialytic weight gain, compliance with dialysis regimen, and age are independent predictors of blood pressure in hemodialysis patients. Am J Kidney Dis 35(2):257–265
14. Dumler F, Kilates C (2003) Body composition analysis by bioelectrical impedance in chronic maintenance dialysis patients: comparisons to the National Health and Nutrition Examination Survey III. J Renal Nutr 13(2):166–172
15. Dumler F (2004) Best method for estimating urea volume of distribution: comparison of single pool variable volume kinetic modeling measurements with bioimpedance and anthropometric methods. ASAIO J 50(3):237–241
16. Wizemann V, et al., Differences in hydration status between healthy, Pre-ESRD, dx and tx subgroups can be distinguished clearly with bioimpedance spectroscopy. Physiol Meas, 2006: p. 1
17. Dal Cin S et al (1992) Role of bioelectrical impedance analysis in acutely dehydrated subjects. Clin Nutr 11(3):128–133
18. Lindqvist P, Henein M, Kazzam E (2003) Right ventricular outflow-tract fractional shortening: an applicable measure of right ventricular systolic function. Eur J Echocardiography 4(1):29–35
19. Nishimura RA, Tajik AJ (1997) Evaluation of diastolic filling of left ventricle in health and disease: doppler echocardiography is the clinician's Rosetta Stone. J Am Coll Cardiol 30(1):8–18
20. Barberato SH et al (2004) Effect of preload reduction by hemodialysis on left atrial volume and echocardiographic Doppler parameters in patients with end-stage renal disease. Am J Cardiol 94(9):1208–1210
21. Hayashi SY et al (2004) Improvement of cardiac function after haemodialysis quantitative evaluation by colour tissue velocity imaging. Nephrol Dial Transplant. 19(6):1497–1506
22. Galetta F et al (2006) Acute effects of hemodialysis on left ventricular function evaluated by tissue Doppler imaging. Biomed Pharmacother 60(2):66–70
23. Miller D et al (2004) The relation between quantitative right ventricular ejection fraction and indices of tricuspid annular motion and myocardial performance. J Am Soc Echocardiogr 17(5):443–447
24. Nagueh SF et al (2001) Hemodynamic determinants of the mitral annulus diastolic velocities by tissue Doppler. J Am Coll Cardiol 37(1):278–285
25. Bjällmark A et al (2011) Effects of hemodialysis on the cardiovascular system: quantitative analysis using wave intensity wall analysis and tissue velocity imaging. Heart Vessels 26(3):289–297
26. Özdemir K et al (2007) Effect of preload and heart rate on the Doppler and tissue Doppler-derived myocardial performance index. Clin Cardiol 30(7):342–348
27. Cavalcanti S, Cavani S, Santoro A (2002) Role of short-term regulatory mechanisms on pressure response to hemodialysis-induced hypovolemia. Kidney Int 61(1):228–238
28. Spiegel D, Bashir K, Fisch B (2000) Bioimpedance resistance ratios for the evaluation of dry weight in hemodialysis. Clin Nephrol 53(2):108–114
29. Moissl UM et al (2006) Body fluid volume determination via body composition spectroscopy in health and disease. Physiol Meas 27(9):921

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