Original Article

Hemodialysis Parameters and Pulse Wave Velocity

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Abstract

Aim: The study aimed to evaluate the acute effect of ultrafiltration on the mechanical properties of the aorta using brachial-ankle pulse wave velocity (PWV) before and after hemodialysis (HD). **Patients and Methods:** This study included 80 patients who were on a long-term HD program. The input variables were anamnestic data, body composition monitor (BCM) parameters, and echocardiography findings. The assessment of hydration status was determined by BCM, whose work is based on the principle of multifrequency bioimpedance spectroscopy. Another diagnostic procedure was the use of an arteriograph apparatus to assess PWV and Augmentation Index (AIx). All measurements were performed before and after dialysis on the middle dialysis day of the week. **Results:** The participants were divided into two groups based on hydration status: the experimental group consisted of 40 overhydrated participants and the control group consisted of 40 normovolemic participants. Statistically, the following BCM parameters correlated significantly positively with PWV: total body fat ($r = 0.222$; $P < 0.05$), overhydration ($r = 0.290$; $P < 0.001$), and relative overhydration ($r = 0.290$; $P < 0.001$). From echocardiography findings, only left atrial diameter correlated statistically significantly positively with PWV ($r = 0.359$; $P < 0.001$). Comparison of the mean PWV values within the experimental group before and after HD showed a statistically significant decrease from 14.32 ± 2.34 m/s to 8.72 ± 1.52 m/s ($Z = 3.254$; $P = 0.0001$). Mean PWV values within the control group did not decrease significantly from 13.39 ± 1.32 m/s to 10.39 ± 1.18 m/s ($Z = 0.524$; $P = 0.742$). If we compare the mean values of PWV between groups, then before HD treatment, there was no statistically significant difference between groups with PWV values in the experimental group of 14.32 ± 2.34 m/s and the control group of 13.39 ± 1.32 m/s ($Z = 0.762$; $P = 0.852$). According to the results of univariate regression analysis before and after HD treatment, only overhydration showed an absolute effect on PWV before and after HD. **Conclusion:** Overhydration showed an effect on brachial-ankle PWV before and after HD, and brachial-ankle PWV should be followed in HD patients.

Keywords: *Chronic kidney disease, hemodialysis, pulse wave velocity*

Introduction

Chronic kidney disease (CKD) is one of the biggest public health problems in developed countries.[1] From the analysis of epidemiological data in these countries, it is deducible that 10% of the adult population faces the problem of CKD.[2] There is an increased risk of pathological changes in many organs in people with CKD, with a particular risk of cardiovascular disease (CVD).[3] Atherosclerosis is a chronic inflammatory disease that is characterized by endothelial dysfunction, deposition of extracellular and intracellular lipids in the tunica intima, proliferation of smooth muscle cells, accumulation of connective tissue proteins, cell necrosis and apoptosis, as well as the involvement of the innate and acquired immune systems in response.[4] The early manifest phase of the atherosclerotic process is endothelial dysfunction and represents an indicator of cardiovascular mortality.[4] Pulse wave velocity (PWV), the most widely used measure of arterial stiffness, has emerged as a valuable tool for the diagnosis and risk stratification of CVD. PWV is the measure of the speed of arterial pressure waves traveling along the aorta and large arteries (indicators of arteriosclerosis), and it is usually calculated by dividing distance by pressure wave transit time at the two points of recording arteries.[5] It is based on the fact that it spreads to blood vessels that are more or less affected by the atherosclerotic process, and consequently stiffer or more elastic and bounces off from the periphery back to the heart. It bounces faster if the arteries are stiffer,

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Table 1: Demographic data in hemodialysis patients

	Experimental group		Control group		Total	
	Male	Female	Male	Female	Male	Female
Age	56.17±10.28 (27-70)	51.32±11.85 (34-69)	55.32±11.77 (27-76)	51.74±2.76 (36-75)	53.50±11.30 (27-70)	55.58±11.61 (27-76)
P	0.180		0.879		0.420	
Body weight (kg)	82.47±13.46 (61.0-101.2)	74.19±17.19 (51.5-107.0)	84.85±12.30 (55.7-110.5)	69.67±10.6 (50.6-88.7)	77.92±15.98 (51.5-107.0)	78.02±13.75 (50.6-110.5)
P	0.104		0.0001		0.979	
Body height (cm)	177.05±9.28 (164-193)	165.5±9.07 (153-184)	174.86±9.42 (161-195)	160.5±8.87 (148-181)	170.7±10.76 (153-193)	168.40±11.60 (148-195)
P	0.0001		0.0001		0.361	
BMI (kg/m2)	25.68±3.41 (16.6-31.6)	27.01±5.56 (20.1-38.4)	27.598±3.66 (21.2-34.6)	27.25±5.27 (19-37.9)	26.41±4.64 (19.6-38.36)	27.44±4.40 (19.0-37.9)
P	0.374		0.806		0.312	
Male (%)	18 (45.0)		22 (50.0)			
Female (%)	22 (50.0)		18 (45.0)			
P	0.251					

BMI: Body mass index

i.e. more affected by the atherosclerotic process; the heart is, therefore, more burdened because the blood returns in late systole and the filling decreases in coronary arteries in diastole, leading to the development of cardiomyopathy, coronary heart disease, and cerebrovascular insults.[6] The influence of hydration status on PWV is not sufficiently elucidated,[7] and the determination of hydration status by BCM (bioimpedance spectroscopy) in hemodialysis (HD) patients is a new method that can contribute to the evaluation of PWV as a new risk factor of cardiovascular morbidity. The question is whether the overhydrated patients will have high PWV as well as whether there are more significant differences in PWV values before and after treatment, especially in patients with advanced atherosclerosis and consequently impaired hydration status, which will lead to increased CV morbidity.

The aim of this article is to evaluate the acute effect of ultrafiltration on the mechanical properties of the aorta using PWV before and after HD.

Patients and Methods

Patients and study design

The research was conducted at the Clinical Center University of Sarajevo. This study included 80 patients who were on a long-term HD program three times a week with a duration of 4 h at the clinic for HD. Inclusion criteria in the study were: informed consent; age >18 years old; receiving HD treatment for at least 6 months; no evidence of CVD 6 months before the study as per anamnestic data without any cardiovascular pathology; clinically stable dry weight. According to the exclusion criteria, the following patients were excluded from this study: patients with amputated limbs, patients with atrial fibrillation, patients with malignancy, and patients with an implanted electrostimulator or defibrillator.

At the beginning of the study, patients were divided into two groups of 40 participants. They were categorized into experimental and control groups. One group would consist of patients who are overhydrated, and the other group would be normovolemic patients. Patients were matched by gender and age as much as possible. The experimental group consisted of 18 males (45%) and 22 females (50%), while in the control group, there were 22 males (50%) and 18 females (45%).

The parameters that were followed during this study were age and gender, time spent on dialysis, and primary kidney disease, leading to the terminal stage. Patient anamnesis, past medical history, laboratory parameters, and medication data were collected from medical records. Patients were under therapy with erythropoietin and active Vitamin D. All patients were dialyzed with standard bicarbonate solutions and synthetic membranes with an average blood flow of 300–350 ml/min and dialysis flow of 500–800 ml/min with a target dialysis dose of (Kt/V) >1.2; therefore, they were dialyzed three times a week. A total of 74.4% were dialyzed via an arteriovenous fistula and 15.4% via a permanent central venous catheter. About 54% were on antihypertensive therapy, 2.8% of those were treated with angiotensin-converting enzyme inhibitors, 12% with angiotensin II type receptor blockers, and 15.3% with other vasodilators. About 83% of patients received active Vitamin D (calcitriol). About 77% of patients were on phosphate binders (calcium carbonate and sevelamer). All patients received folic acid, while 37% (20.4%) of patients took statins, and 17.5% were on antiplatelet therapy.

Methods

The input variables used were anamnestic data, body composition monitor (BCM parameters (body cell mass index (BCM), extracellular-to-intracellular (E/I) body water

ratio, fat tissue index (FTI), lean tissue index (LTI), lean tissue mass (LTM), total body fat, overhydration, relative overhydration, expected relative hydration after dialysis), and echocardiography findings. The assessment of hydration status was determined by BCM, whose work is based on the principle of multifrequency bioimpedance spectroscopy. Another diagnostic procedure was the use of an arteriograph apparatus to assess brachial-ankle PWV. All measurements of arterial pressure and vascular stiffness were performed before and after dialysis on the middle dialysis day of the week. Patients were warned not to take caffeinated beverages before the test and to refrain from using cigarettes. Blood pressure and heart rate were measured with a digital blood pressure monitor. We used bracelets standard (24 cm–32 cm) and large (32 cm–38 cm). AP was measured three times at 3-min intervals between measurements. The calculated mean value was obtained by the second and third measurements. Arterial hypertension was defined as pressure > or equal to 140/90 mmHg. Pulse pressure amplification was defined as the absolute difference between brachial and central pulse pressure, while the amplification ratio was determined as the ratio of brachial and central pulse pressure. Arterial stiffness was determined by two markers, PWV and Augmentation Index (AIx). It was done by Tensiomed Arteriograph device (Medexpert Ltd., Budapest, Hungary), a computerized device (with software) that uses an oscillometric method to measure brachial arterial pressure. After patients signed an informed consent, in which they were informed of the procedures they would undergo during the clinical study, the following measurements were performed. Ethical approval was obtained from the Ethical Committee of the Clinical Center University of Sarajevo, Ethical Committee No. 01-4-AK-3657/19 (13.06.2019.).

Statistical analysis

Since the data do not meet the normal distribution criteria, the comparison was performed using the Mann–Whitney test with the display of Z and *P* values in the table(s). Correlation analysis was performed using the Pearson linear correlation coefficient in the total sample to examine the association or influence of parameters on PWV. A statistical level of 95% ($P < 0.05$) was taken as significant.

Results

The participants were divided into two groups based on hydration status: the experimental group consisting of 40 overhydrated participants and the control group consisting of 40 normovolemic participants [Table 1]. A comparative analysis of the mean age by gender showed that women were slightly younger than men, both in the total sample and within individual groups but without statistically significant differences, indicating that the selected sample was homogeneous by age. There was no statistically significant difference in the comparison of body cell mass index (BCM) between experimental and control groups (23.93 ± 8.16 kg vs. 21.59 ± 6.08 kg, $P > 0.05$), mean FTI (LTI) (12.80 ± 5.09 kg/m² vs. 11.94 ± 6.12 kg/m², $P > 0.05$), mean LTI (14.34 ± 2.82 kg/m² vs. 14.32 ± 3.21 kg/m², $P > 0.05$), LTM (42.9 ± 12.46 kg vs. 39.46 ± 10.68 kg, $P > 0.05$), total body fat (21.65 ± 9.95 kg vs. 24.93 ± 10.69 kg, $P > 0.05$), and mean values of expected relative hydration after dialysis (2.66 ± 2.24 L vs. 3.35 ± 2.83 L, $P > 0.05$). Furthermore, there was no statistically significant difference between mean values of systolic blood pressure (142.28 ± 23.69 mmHg vs. 140.13 ± 19.3 mmHg, $P > 0.05$), mean values of diastolic blood pressure (80.52 ± 11.76 mmHg vs. 80.75 ± 9.17 mmHg; $P > 0.05$), left ventricular ejection fraction (53.57 ± 7.31% vs. 52.42 ± 6.98%; $P > 0.05$), values of left ventricular end-diastolic diameter (LVDd) (4.81 ± 0.78 cm vs. 4.79 ± 0.77 cm; $P > 0.05$), basal right ventricle diameter (3.49 ± 0.73 cm, vs. 3.51 ± 0.65 cm; $P > 0.05$), values of left ventricular posterior wall end-diastole diameter (LVDs) (1.06 ± 0.23 cm vs. 1.07 ± 0.2 cm), and values of interventricular septum end-diastole diameter (1.49 ± 0.13 cm vs. 1.54 ± 0.43 cm). A comparison of the mean values of the E/I body water ratio between the experimental and control groups showed that the ratio was significantly higher in the experimental group with a mean of 5.75 ± 18.67 compared to the control group with a mean of 1.26 ± 0.87 ($P < 0.05$). A comparison of the mean values of overhydration between the experimental and control groups showed that it was on average higher in the experimental group with a mean of 3.85 ± 2.01 L compared to the control group with a mean of 1.39 ± 0.93 L ($P < 0.05$). The same was proved for relative overhydration (L) (23.18 ± 12.11 L vs. 8.37 ± 5.61 L; $P < 0.05$).

The diameter of the aorta was smaller in the experimental group, with a mean of 3.04 ± 0.48 mm compared to the control group's mean of 3.23 ± 0.46 mm ($P < 0.05$), but the left atrial diameter was greater, with a mean of 4.54 ± 0.62 mm in experimental group participants compared to the control group's mean of 3.33 ± 0.5 mm ($P > 0.05$). A comparison of the mean AIx values between the experimental and control groups revealed that the mean was significantly higher in the experimental group participants (40.17 ± 10.01%) compared to the control group (21.83 ± 8.6%) ($P < 0.05$). Moreover, the PWV was higher in participants of the experimental group (10.32 ± 1.52 m/s) compared to the control group (9.4 ± 1.3 m/s) ($P < 0.05$). The pulse wave return time was far shorter in the experimental group (107.94 ± 15.74 ms) compared to the control group (121.61 ± 17.67 ms). There is a statistically significant difference between the two groups ($P < 0.05$). Comparing the mean values of systolic aortic pressure between the two groups revealed that the experimental group participants had a considerably higher aortic systolic pressure (141.96 ± 15.12 mmHg) than the control group (127.78 ± 15.22 mmHg). Statistical analysis indicates a statistically significant

difference ($P < 0.05$) between the experimental and control groups. The experimental group's mean aortic pressure (99.19 ± 9.94 mmHg) was higher than that of the control group (94.31 ± 14.62 mmHg), without a statistically significant difference between the two groups. Furthermore, the central pulse pressure mean value in the experimental group was 54.91 ± 8.09 mmHg, and in the control group, the mean was 53.52 ± 6.48 mmHg, with no statistically significant difference between the two groups. Correlation analysis was performed using the Pearson linear correlation coefficient in the total sample to examine the association or effect of body composition parameters on PWV [Table 2]. The parameters do not demonstrate a correlation with PWV; this is understandable because the groups do not differ significantly according to these parameters. Statistically, body weight and height were significantly positively correlated ($r = 0.574$; P (bidirectional testing) <0.001) and body weight with body mass index ($r = 0.636$; P (bidirectional testing) <0.001). Statistically, the following BCM parameters correlated significantly positively with PWV: total body fat ($r = 0.222$; $P < 0.05$), overhydration ($r = 0.290$; $P < 0.001$), and relative overhydration ($r = 0.290$; $P < 0.001$) [Table 3]. Only left atrial diameter correlated statistically significantly positively with PWV ($r = 0.359$; $P < 0.001$) [Table 4]. AIx aortic ($r = 0.381$; $P < 0.001$) correlated significantly positively with PWV, along with aortic systolic pressure (r = 0.251; $P < 0.05$), central pulse pressure ($r = 0.271$; $P < 0.05$), and negatively with pulse wave return time ($r = -0.948$; $P < 0.001$) [Table 5]. Comparison of the mean PWV values within the experimental group before and after HD showed a statistically significant decrease from 14.32 ± 2.34 m/s to 8.72 ± 1.52 m/s ($Z = 3.254$; $P = 0.0001$). Mean PWV values within the control group did not decrease significantly [Table 6]. Comparison of the mean PWV values within the experimental group before and after HD showed a statistically significant decrease from 14.32 ± 2.34 m/s to 8.72 ± 1.52 m/s ($Z = 3.254$; $P = 0.0001$). Mean PWV values within the control group did not decrease significantly from 13.39 ± 1.32 m/s to 10.39 ± 1.18 m/s ($Z = 0.524$; $P = 0.742$) [Table 6]. If we compare the mean values of PWV between groups, then before HD treatment, there was no statistically significant difference between groups with PWV values in the experimental group of 14.32 ± 2.34 m/s and the control group of 13.39 ± 1.32 m/s, with $Z = 0.762$;

Table 2: Correlation between pulse wave velocity and anamnestic data

	Age	Body weight (kg)	Body height (cm)	BMI (kg/m²)
PWV (m/s)				
r	−0.078	0.020	0.085	−0.006
P	0.491	0.859	0.451	0.957
n	80	80	80	80
Age				
r		0.032	−0.043	0.058
P		0.779	0.705	0.612
n		80	80	80
Body weight (kg)				
r			0.574**	0.636**
P			0.000	0.000
n			80	80
Body height (cm)				
r				−0.218
P				0.053
n				80

**$P < 0.05$. BMI: Body mass index; PWV: Pulse wave velocity

Table 3: Correlation between pulse wave velocity and body composition monitor parameters

	PWV (m/s)
BCM (kg)	
r	0.039
P	0.731
n	80
E/I body water ratio	
r	0.058
P	0.612
n	80
FTI (kg/m²)	
r	0.098
P	0.390
n	80
LTI (kg/m²)	
r	−0.206
P	0.066
n	80
LTM (kg)	
r	0.005
P	0.967
n	80
Total body fat (kg)	
r	0.222*
P	0.047
n	80
Overhydration (L)	
r	0.290**
P	0.009
n	80
Relative overhydration (L)	
r	0.290**
P	0.009
n	80
Expected relative hydration after dialysis (L)	
r	−0.052
P	0.648
n	80

**$P < 0.05$. BCM: Body cell mass index; E/I: Extracellular-to-intracellular; FTI: Fat tissue index; LTI: Lean tissue index; LTM: Lean tissue mass; PWV: Pulse wave velocity

Table 4: Correlation between pulse wave velocity and echocardiographic parameters

	PWV (m/s)
Systolic blood pressure (mmHg)	
r	0.063
P	0.578
n	80
Diastolic blood pressure (mmHg)	
r	0.135
P	0.231
n	80
Ejection fraction of left ventricle (%)	
r	−0.028
P	0.803
n	80
Aortic diameter (cm)	
r	−0.123
P	0.276
n	80
Left atrial diameter (cm)	
r	0.359**
P	0.001
n	80
Right ventricle (basal diameter) (cm)	
r	0.025
P	0.824
n	80
LVDd (cm)	
r	0.170
P	0.131
n	80
LVDs (cm)	
r	0.069
P	0.546
n	80
IVSd (cm)	
r	0.141
P	0.212
n	80

**$P < 0.05$. PWV: Pulse wave velocity; IVSd: Interventricular septum end-diastole diameter; LVDs: Left ventricular posterior wall end-diastole diameter; LVDd: Left ventricular end-diastolic diameter

$P = 0.852$. The mean PWV values after HD treatment showed a statistically significant difference with values in the control group of 8.72 ± 1.52 m/s and values in the experimental group of 13.39 ± 1.32 m/s, with $Z = -4.346$; $P = 0.0001$. According to the results of univariate regression analysis before and after HD treatment, only one parameter showed an absolute effect before and after– overhydration. Other observed factors that showed an effect, but only after HD treatment, include age, body weight, aortic blood pressure, overhydration, E/I body water ratio, relative overhydration, and left atrial diameter [Table 7].

Table 5: Correlation between pulse wave velocity and arteriographic parameters

	PWV (m/s)
Aix aortic (%)	
r	0.381**
P	0.000
n	80
Return time of the pulse wave (ms)	
r	−0.948**
P	0.000
n	80
Central aortic pressure (mmHg)	
r	0.251*
P	0.025
n	80
Mean aortic pressure (mmHg)	
r	0.096
P	0.396
n	80
Central pulse pressure (mmHg)	
r	0.271*
P	0.015
n	80

**$P < 0.05$. PWV: Pulse wave velocity

Discussion

PWV holds diagnostic and prognostic relevance in assessing CVD in CKD patients and could thus serve as a surrogate marker to reduce the burden of CVD in the CKD population.[8] In addition, during HD, variations in PWV are attributed to changes in arterial wall elasticity.[9]

In patients with end-stage renal disease, arterial stiffness increases at an earlier age when compared to the general population, contributing to the overall risk of cardiovascular mortality. Ferreira *et al*. stated that in ESRD patients under 60 years of age, a PWV >12 m/s provides important prognostic information, but its relevance is lost in older patients.[10] Aortic-brachial PWV was measured using the Tensio Clinic Ateriograph (TensioMed Kft., Budapest, Hungary), which has been validated against direct invasive measurements, as this technique completely stops blood flow, removing the influence of the Bernoulli effect. It has also been shown to be the most reproducible of the currently available devices for measuring PWV, as it is simple to use in the clinical setting.[11] In the general population, PWV increases with age, and this is especially pronounced when BP levels are higher. On the other hand, the increase in PWV with age may be considerably less if there are no CV risk factors.[12]

AIx is a maker of arterial rigidity that could be affected by the patient's hemodynamics.[13] Our study proved that significantly higher values were in overhydrated subjects, which indicates that the volume overload, and thus the

Table 6: Pulse wave velocity before and after hemodialysis

	Number	Mean±SD	Standard error of the mean	Minimum	Maximum
PWV (m/s) before hemodialysis					
Overhydrated	40	14.32±2.34	0.24101	11.15	17.87
Normovolemic	40	13.39±1.32	0.20543	10.60	15.70
Total	80	13.86±1.48	0.16567	10.60	17.87
PWV (m/s) after hemodialysis					
Overhydrated	40	8.72±1.52	0.24101	5.55	12.27
Normovolemic	40	10.39±1.18	0.20543	7.60	12.70
Total	80	9.56±1.64	0.18	5.55	12.70

PWV: Pulse wave velocity; SD: Standard deviation

Table 7: Univariate regression analysis of the effect of clinical, laboratory, and body composition parameters on pulse wave velocity

PWV (m/s)	Prior to hemodialysis		After hemodialysis	
	r	*P*	*r*	*P*
Age	0.192	0.146	0.457	0.0001
Body weight (cm)	0.215	0.078	−0.485	0.0001
Body height (kg)	0.133	0.314	0.239	0.069
Central aortic pressure (mmHg)	0.203	0.124	0.459	0.0001
BCM (kg)	0.177	0.215	0.246	0.082
E/I body water ratio	0.078	0.568	−0.145	0.286
FTI (kg/m^2)	0.011	0.999	0.081	0.985
LTI (kg/m^2)	−0.052	0.730	−0.022	0.883
LTM (kg)				
Total body fat (kg)	0.140	0.307	0.496	0.0001
Overhydration (L)	−0.376	0.024	0.447	0.0001
Relative overhydration (L)	0.126	0.359	0.485	0.0001
Expected relative hydration after dialysis (L)	−0.224	0.190	−0.258	0.134
Systolic blood pressure (mmHg)	0.006	0.965	−0.205	0.120
Diastolic blood pressure (mmHg)	0.094	0.479	−0.017	0.900
Ejection fraction of left ventricle (%)	0.197	0.149	0.039	0.824
Aortic diameter (cm)	0.203	0.124	0.059	0.884
Left atrial diameter (cm)	0.184	0.257	0.482	0.0001
Right ventricle (basal diameter) (cm)	0.197	0.149	0.105	0.447
LVDd (cm)	0.126	0.359	−0.172	0.209
LVDs (cm)	0.276	0.175	0.029	0.845
Interventricular septum end diastole diameter (cm)	0.153	0.246	0.195	0.085

PWV: Pulse wave velocity; FTI: Fat tissue index; LTI: Lean tissue index; LTM: Lean tissue mass; E/I: Extracellular-to-intracellular; BCM: Body cell mass index; LVDd: Left ventricular end-diastolic diameter; LVDs: Left ventricular posterior wall end-diastole diameter

remodeling of the left ventricle, or a smaller ejection fraction of the left ventricle, affects the same. PWV was higher also in the same group, demonstrating that volume loading has an effect on higher PWV values. Similarly, a study by Cabrera-Fischer *et al*. analyzed the association between hydration status and PWV ratio in hemodialyzed patients and found that patients in HD, who had higher values of PWV ratio, carried a higher mortality risk.[14] Perhaps, the most important independent prognostic factor determining the outcome of HD patients is volume overload.[15] Assessing fluid overload can help in regressing the left ventricular mass index, reducing blood pressure, as well as improving arterial stiffness.[16] Yet, volume load optimization is a challenge in everyday work.

HD causes significant changes in volume loading and blood pressure as a function of ultrafiltration.[8] In dialysis patients, chronic fluid overload increases the cardiac load.[16,17] Hence, hypertension and left ventricular hypertrophy in HD patients are primarily caused by fluid overload.[16] PWV is independently related to cardiovascular outcomes in dialysis patients.[18] It should also be emphasized that it predicts adverse cardiovascular outcomes in the general population and patients with CVD s.[19] In patients who receive HD regularly, diastolic dysfunction is an independent predictor of mortality and hospitalization.[20] Increased arterial stiffness has been linked to diastolic dysfunction in the left ventricle (LVDD); therefore, echocardiographic estimation of PWV is a sensitive and reliable method for verifying

LVDD, and it carries favorable prognostic implications in such patients.[21] If patients have PWW >10 cm/s, they have higher NT per BNP, while patients with higher PWV had diastolic dysfunction on echocardiography.[22] In our study, LA diameter correlates with diastolic dysfunction, and overhydration correlates with diastolic dysfunction. PWV value ≥10 m/s is the threshold for increased risk.[23]

The question is how to understand patients on HD, i.e. due to the volume load, whether to understand them as heart failure with preserved ejection fraction. Therefore, echocardiography should be a routine part of the therapeutic follow-up of HD patients.

Increased aortic PWV independently predicted adverse clinical outcomes (death or hospitalization) among patients with heart failure.[24]

PWV correlated with age, weight, height, and blood pressure,[25] but our study has not proven the same. PWV is a predictor of morbidity and mortality in patients with HD, and daily dialysis may be used in patients with high PWV levels to reduce their mortality risk.[26]

In our study, PWV before and after HD treatment was only related to overhydration, as it was proven that HD itself has an effect on reducing PWV, regardless of volume status in the beginning.

Conclusion

Overhydration showed an effect on brachial-ankle PWV before and after HD (HD), and brachial-ankle PWV should be followed in HD patients.

Ethical statement

Ethical approval was obtained from the Ethical Committee of the Faculty of Medicine, University of Sarajevo, Ethical Committee No. 01-4-AK-3657/19 (13.06.2019).

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Conflicts of interest

There are no conflicts of interest.

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