



Echocardiographic Assessment of Right Ventricular Function in Haemodialysis Patients

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Abstract

Background: Chronic renal failure (CRF) affects almost every system of the body. Cardiovascular disease (CVD) in patients undergoing dialysis appears to be far greater than in the general population and is considered the leading cause of mortality, accounting for 50% of deaths. In particular, heart failure (HF) is the most common finding in these patients and is associated with poor prognosis. Haemodialysis (HD), which is usually carried out via a surgically-created arteriovenous fistula has been associated with volume/pressure overload, leading to increased risk of developing pulmonary hypertension (PHT), a condition reported as a predictor of mortality in these patients.

Objectives: This study is designed to investigate the impact of chronic dialysis therapy on right ventricular (RV) function using conventional and speckle tracking echocardiography (STE).

Methods: This study was conducted at the Cardiology Department of Menoufia University Hospital from October 2018 to October 2019, and was carried out on 50 patients (group I) with end-stage renal disease (ESRD) on regular haemodialysis for at least 1 month, and receiving haemodialysis sessions 3 times per week and each session lasts about 4 hours, of both sexes. And compared with 20 normal healthy volunteers (group II), free from cardiovascular risk factors, age and sex matched. All patients were subjected to full history taking, clinical examination, electrocardiographic (ECG) tracing and echocardiographic assessment.

Results: Compared to control group, HD patients had increased CVD risk factors like hypertension (HTN) and diabetes mellitus (DM). RV preload and afterload were increased, with increased prevalence of pulmonary artery hypertension (PHT). RV systolic function was significantly reduced, as evidenced by reduced tricuspid annular plane systolic excursion (TAPSE), fractional area change (FAC), Tri S', strain and strain rate. Also, diastolic function was impaired, as evidenced by reduced Tri E/A and Tri E'/A'. HD patients also had increased prevalence of left ventricular hypertrophy (LVH) and increased left atrial (LA) diameter. On the other hand, there was no significant difference between the two groups regarding age, sex, aortic diameter and left ventricular ejection fraction (LV EF).

Conclusion: HD was associated with RV volume/ pressure overload resulting in systolic and diastolic dysfunction. HD patients had decreased TAPSE, FAC, Tri S', Tri E/A, Tri E'/A' and speckle tracking-derived strain and strain rate, and increased tricuspid A wave velocity. HD was also associated with increased prevalence of PHT. Speckle tracking echocardiography is new technique that can detect early and subclinical changes, and thus, can be used for early detection and follow up of RV dysfunction in HD patients.

Keywords: Right ventricular dysfunction; Haemodialysis; Speckle tracking echocardiography

Introduction

Chronic renal failure (CRF) affects almost every system of the body and results in various functional and structural

abnormalities. Cardiovascular disease (CVD) in patients undergoing dialysis appears to be far greater than in the general population and is considered the leading cause of mortality, accounting for 50% of deaths [1]. In particular, heart failure (HF)

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is the most common finding in these patients and is associated with poor prognosis [2]. Most of the available studies regarding the relation between pulmonary hypertension (PHT) and dialysis have mostly investigated the impact of volume overload on tissue Doppler imaging indices of left ventricular function, showing an increased prevalence of diastolic dysfunction in these patients [3,4]. But the impact of dialysis and related treatments on the development of right ventricular dysfunction has not been fully investigated [5]. Haemodialysis (HD), which is usually carried out via a surgically-created arteriovenous fistula has been associated with volume/pressure overload, leading to increased risk of developing PHT (incidence rate: 17-60%), a condition reported as a predictor of mortality in these patients [6-10]. Speckle-tracking echocardiography (STE) is a new non-invasive ultrasound imaging technique that allows for an objective and quantitative evaluation of global and regional myocardial function [11].

Aim of the Work

The aim of the work is to assess the right ventricular function in haemodialysis patients by different echocardiographic modalities.

Materials and Methods

Study population

It is a single-centre, prospective study that was conducted at Cardiology department of Menoufia University Hospital in Menoufia, Egypt from October 2018 to October 2019. The study was carried out on 50 patients (group I) with ESRD on regular HD, and compared with 20 normal healthy volunteers (group II), free from cardiovascular risk factors, age and sex matched.

Inclusion criteria

Patients on regular haemodialysis for at least 1 month, and receiving haemodialysis sessions 3 times per week and each session lasts about 4 hours, of both sexes.

Exclusion criteria

Patients with any of the following: atrial fibrillation, pacemaker or defibrillator leads in the RV, sustained arrhythmias, RV infarction, cardiogenic shock, organic valve diseases, congenital heart disease, renal transplantation, any clinical condition that might predispose to PHT e.g. chronic obstructive pulmonary disease, pericardial diseases, debilitating diseases e.g. liver diseases & cancer, and patients with unsatisfying echocardiographic images.

Methodology

1. **Full history taking:** including personal history and history of any risk factors like HTN, DM, history of renal and

cardiac disorders, and history of any other diseases.

2. **Thorough clinical examination:** Including both general and local cardiac examinations with special stress on pulse rate, blood pressure, signs of valvular affection, signs of PHT and signs of HF.
3. **Electrocardiography (ECG):** Resting standard 12 leads ECG was done to assess heart rate and rhythm and to exclude any other abnormalities.
4. **Echocardiography:** Echocardiography was performed using Vivid 9, General Electric Healthcare (GE Vingmed, Norway) equipped with a harmonic M5S variable-frequency (1.7 - 4 MHz) phased-array transducer. All subjects were examined in the left lateral position and connected to single lead ECG. All values represent the mean of 3 measurements taken in 3 consecutive cardiac cycles.

M-mode was applied on parasternal long-axis view (PLAX) perpendicular to the LV long axis at the level of aortic valve leaflets to obtain aortic and LA diameters, and at the level of papillary muscles level to obtain end-diastolic thickness of the interventricular septum (IVSd), end-diastolic thickness of the LV posterior wall (PWTd), end-diastolic LV diameter (LVEDd), and end-systolic LV diameter (LVESd). Then LV EF % and fractional shortening (FS %) were calculated to assess the LV systolic function. Pulsed wave Doppler (PW) was applied to both mitral and tricuspid valve leaflets in the apical 4-chamber view. Then E, A waves and E/A ratio of both valves were obtained to evaluate LV and RV diastolic functions respectively. RV dimensions (basal, mid-cavity and longitudinal) were measured in the RV-focused apical 4-chamber view. While right ventricular outflow tract (RVOT) (proximal and distal dimensions) were measured in the PLAX and parasternal short-axis (PSAX) great vessels level. Tissue Doppler imaging (TDI) was performed in the apical 4-chamber view by positioning the sample volume over the lateral tricuspid annulus, then Tri S', Tri E', Tri A' and Tri E'/A' ratio were measured (Figure 4).

RV systolic function assessment was done by measuring FAC, TAPSE and Tri S'. FAC was measured in the apical 4-chamber view by tracing the RV endocardium both in systole and diastole from the annulus, along the free wall to the apex, and then back to the annulus, along the interventricular septum, and was calculated as follow (end-diastolic area - end-systolic area)/end-diastolic area × 100. TAPSE was measured by placing M-mode cursor through the lateral tricuspid annulus and measuring its longitudinal motion at peak systole (Figures 1 and 2).

Systolic pulmonary artery pressure (SPAP) was measured using the simplified Bernoulli equation: $SPAP = 4(V)^2 + RA$ pressure. Where (V) is the maximal tricuspid regurgitation velocity obtained by continuous wave Doppler. Right atrial (RA) pressure was estimated from inferior vena cava (IVC) diameter and respiratory changes [12-14] (Figure 3).

SUNTEXT REVIEWS

STE was performed in the RV-focused apical 4-chamber view at a frame rate of 59-82 frame/s; mean 72+6 frame/s. 3 consecutive beats were acquired at end- expiration breath-holding and digitally stored on a hard disk for offline analysis. ECG leads were connected in order to adjust the timing of cardiac events. Image analysis was performed offline on a personal computer (PC) workstation using custom analysis software (Echopac PC, Version 1.8.1.X, GE Healthcare).

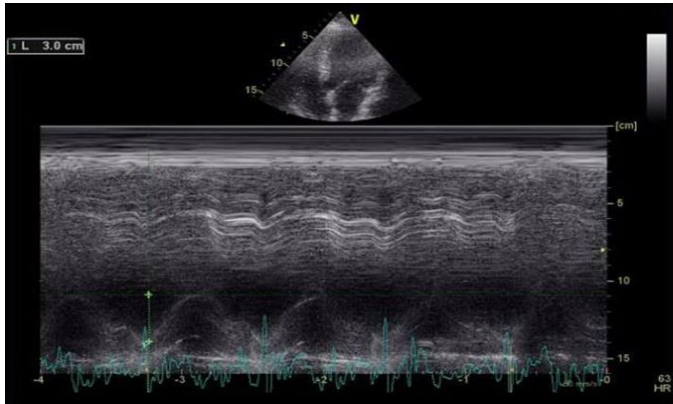


Figure 1: Measuring TAPSE.

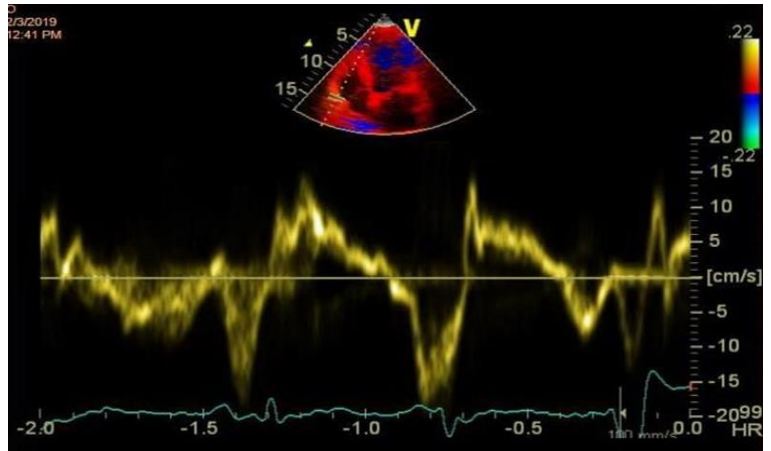


Figure 4: TDI of the lateral tricuspid valve annulus.

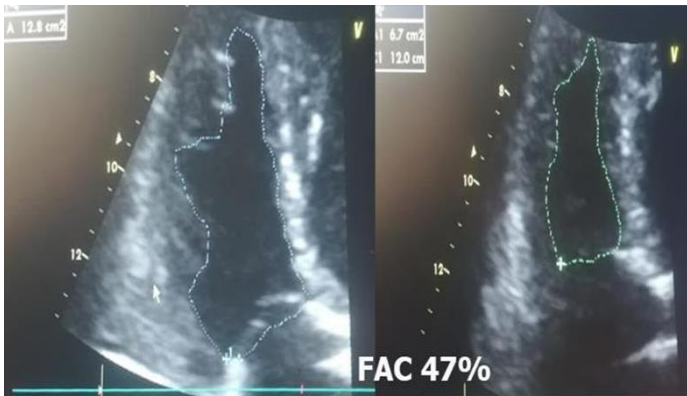


Figure 2: Measuring FAC.

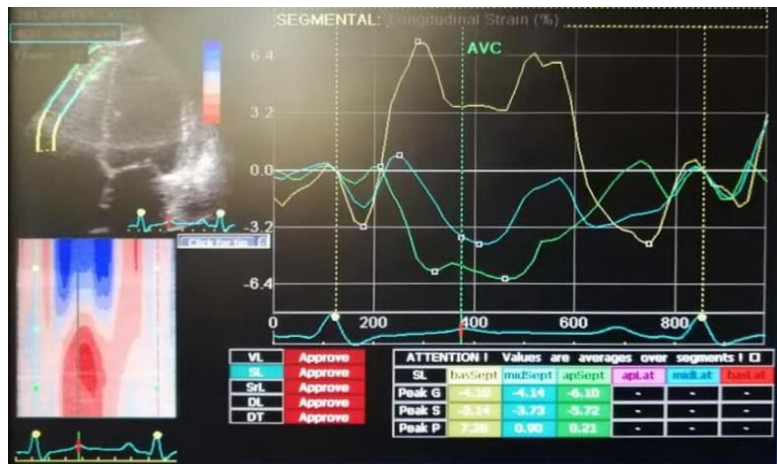


Figure 5: Measuring longitudinal strain of the RV free wall.

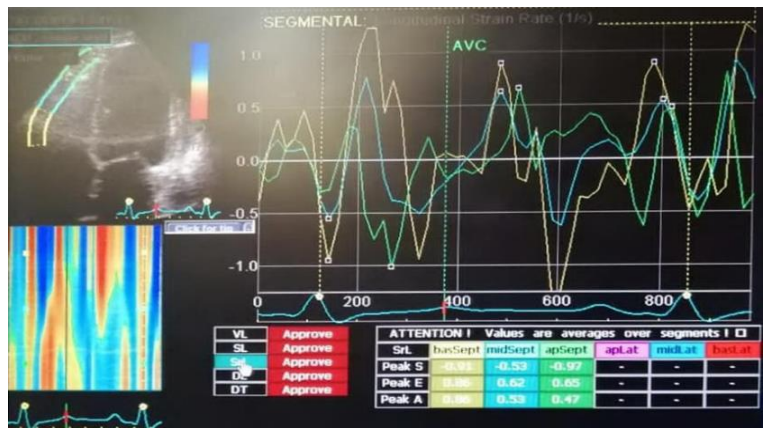


Figure 6: Measuring longitudinal strain rate of the RV free wall.

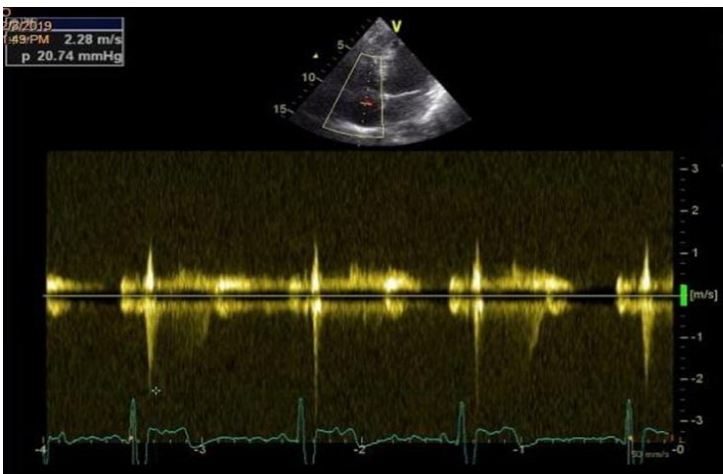


Figure 3: Measuring SPAP.

Using the 2D strain software, The RV endocardial border at end-systole was manually traced. The computer then automatically created a region of interest (ROI) including the entire transmural wall, and the software selected suitable natural acoustic markers (speckles) that move with the tissue for tracking. Longitudinal strain and strain rate curves of each segment of the RV free wall

(the base, the mid-segment and the apex) were generated and analysed. Global RV strain (RS %) was obtained by averaging the strain values of the 3 free wall segments. Also, peak systolic (SRs s⁻¹), peak early diastolic (SRe s⁻¹) and peak late diastolic (SRa s⁻¹) strain rates of each segment were obtained. Global RV systolic and diastolic strain rates were obtained by averaging the strain rate values of the 3 free wall segments (Figures 5 and 6).

Statistical Analysis

Statistical analysis was performed using the statistical package for social science (SPSS) version 26. Patient demographic data were presented as mean and standard deviation (SD) for continuous variables with normal distribution and as percentages for categorical variables. Comparison between two means was done using student "t test" and comparison between three independent

populations was done using One-way ANOVA test. Simple group comparison was performed using χ^2 (Chi-square) test for categorical variables. Correlation analysis was done using Pearson or Spearman if appropriate. P. value < 0.05 was considered significant.

Results

Characteristics of the study population

There was no statistically significant difference between the two groups regarding age and sex. While hypertension and diabetes mellitus were significantly increased in patient group compared to controls (p. value 0.001 and 0.001 respectively) (Table 1).

Table 1: Characteristics of the study population.

		Group I (Patients) N=50	Group II (Controls) N=20	P. value
Age	Range	30 - 75	18 - 67	0.571
	Mean ± SD	50.38 ± 14.87	43.55 ± 14.85	
Sex	Male (%)	21 (42%)	9 (45%)	0.822
	Female (%)	29 (58%)	11 (55%)	
HTN	+ve (%)	22 (44%)	0 (0%)	0.001*
	-ve (%)	28 (56%)	20 (100%)	
DM	+ve (%)	23 (46%)	0 (0%)	0.001*
	-ve (%)	27 (54%)	20 (100%)	

HTN: Hypertension; DM: Diabetes mellitus; SD: standard deviation. * Significant: p<0.05.

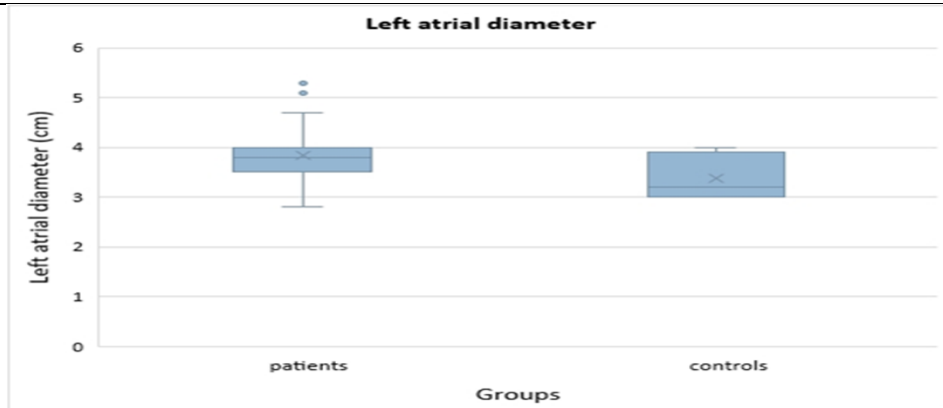


Figure 7: Comparison of left atrial diameter (LA cm) between the two study groups.

Left side conventional echocardiographic parameters

There was no statistically significant difference between the two groups regarding aortic diameter, LVEDD, LVESD and LV EF. While LA diameter, IVSd and LV PWTd were significantly increased in patient group compared to controls (p. value < 0.001, 0.001 and < 0.001 respectively) (Table 2) (Figure 7).

RV conventional echocardiographic parameters

There was no statistically significant difference between the two groups regarding Tri E wave velocity. But SPAP and Tri A wave velocity were significantly increased in patient group compared to controls (p. value 0.002 and 0.006 respectively). While TAPSE, FAC and Tri E/A were significantly reduced in patient group (p.

value < 0.001, < 0.001 and 0.013 respectively) (Table 3) (Figures 8-10).

Table 2: Left side echocardiographic parameters.

Parameter		Patients	Controls	P. value
Ao. (cm)	Range	2.4 - 3.6	2.3 - 3.2	0.193
	Mean ± SD	2.9 ± 0.3	2.63 ± 0.23	
LA. D (cm)	Range	2.8 - 5.3	3.0 - 4.0	< 0.001*
	Mean ± SD	3.84 ± 0.53	3.38 ± 0.41	
IVSd (cm)	Range	0.6 - 1.4	0.5 - 0.9	0.001*
	Mean ± SD	0.88 ± 0.2	0.65 ± 0.15	
LV PWTd (cm)	Range	1 - 1.9	0.4 - 1.2	< 0.001*
	Mean ± SD	1.31 ± 0.25	0.91 ± 0.22	
LVEDD (cm)	Range	3.1 - 6.4	4.2 - 5.7	0.219
	Mean ± SD	5.02 ± 0.69	4.86 ± 0.48	
LVESD (cm)	Range	1.6 - 3.8	2.3 - 3.8	0.845
	Mean ± SD	2.92 ± 0.62	2.87 ± 0.48	
EF (%)	Range	56 - 89	2.3 - 3.8	0.845
	Mean ± SD	72.76 ± 8.23	71.5 ± 7.29	
Ao: Aortic Diameter; IVSd: Inter Ventricular Septum Thickness In Diastole; LVPWTd: Left Ventricular Posterior Wall Thickness In Diastole; LVEDD: Left Ventricular End- Diastolic Diameter; LVSD: Left Ventricular End- Systolic Diameter; EF: Ejection Fraction; LAD: Left Atrium Diameter; SD: Standard Deviation. * Significant: p < 0.05.				

Table 3: Right ventricular 2D echocardiographic parameters.

Parameter		Patients	Controls	P. value
Tri E (m/s)	Range	0.28 - 0.72	0.34 - 0.84	0.818
	Mean ± SD	0.51 ± 0.13	0.51 ± 0.12	
Tri A (m/s)	Range	0.28 - 0.98	0.33 - 0.76	0.006*
	Mean ± SD	0.63 ± 0.17	0.51 ± 0.13	
Tri E/A	Range	0.35 - 1.87	0.63 - 1.64	0.013*
	Mean ± SD	0.89 ± 0.38	1.05 ± 0.36	
TAPSE (cm)	Range	1 - 3.2	1.8 - 3	< 0.001*
	Mean ± SD	1.9 ± 0.45	2.31 ± 0.35	
FAC (%)	Range	30 - 56	40 - 55	< 0.001*
	Mean ± SD	41.7 ± 6.3	47.2 ± 4.58	
SPAP(mmHg)	Range	14 - 75	Aug-30	0.002*
	Mean ± SD	29.6 ± 14.5	18.7 ± 5.46	
Tri E: Tricuspid Annulus Early Diastolic Velocity; Tri A: Tricuspid Annulus Late Diastolic Velocity; Tri E/A: Tricuspid Annulus Early/Late Diastolic Velocity Ratio; TAPSE: Tricuspid Annular Plane Systolic Excursion; FAC: Fractional Area Change; SPAP: Systolic Pulmonary Artery Pressure; SD: Standard Deviation. * Significant: p < 0.05.				

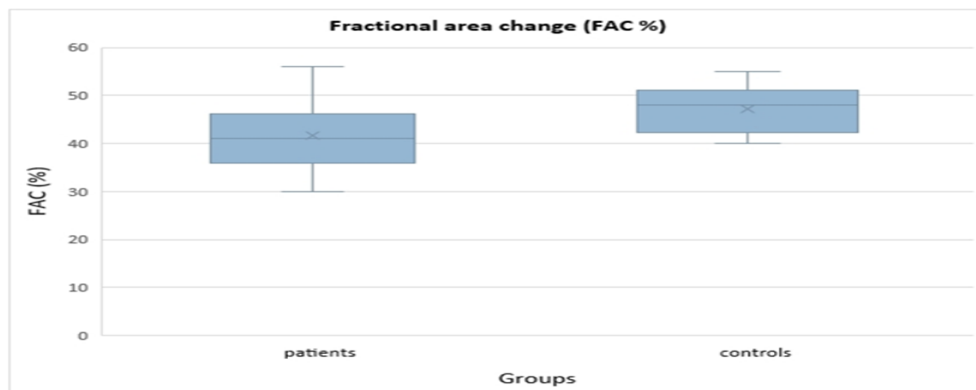


Figure 8: Comparison of fractional area change (FAC %) between the two study groups.

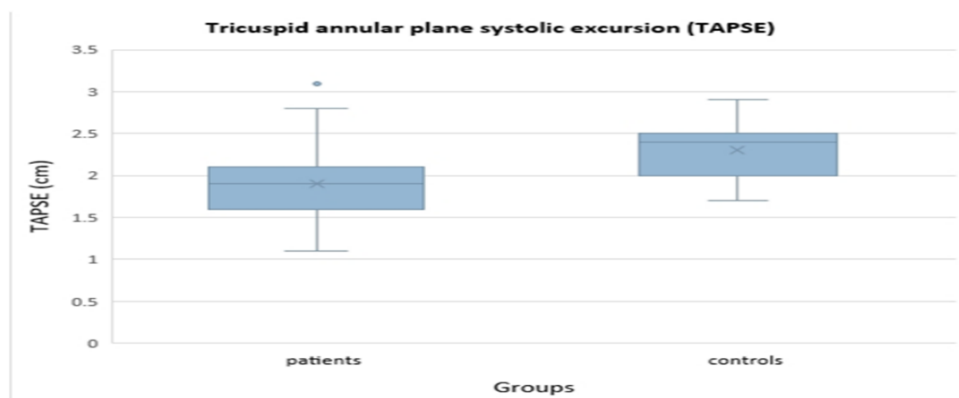


Figure 9: Comparison of tricuspid annular plane systolic excursion (TAPSE) between the two study groups.

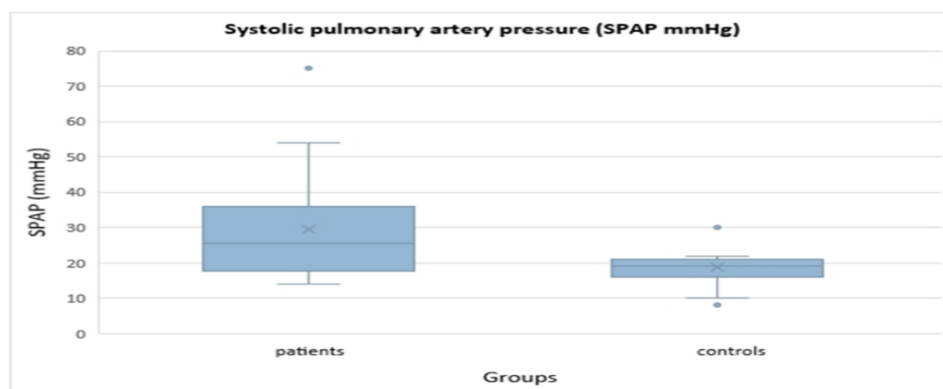


Figure 10: Comparison of systolic pulmonary artery pressure (SPAP mmHg) between the two study groups.

RV tissue Doppler echocardiographic parameters

Tri S' and Tri E'/A' ratio were significantly reduced in patient group compared to controls (p. value 0.002 and 0.001 respectively). And there was no statistically significant difference between the two groups regarding Tri E', Tri A' and Tri E/E' (Table 4) (Figure 11).

RV STE parameters

All strain and strain rate parameters were significantly reduced in patient group compared to controls. They included; RS % (p. value < 0.001), RSRs s⁻¹ (p. value < 0.001), RSRe s⁻¹ (p. value < 0.001) and RSRa s⁻¹ (p. value < 0.001) (Table 5) (Figures 12-15).

Correlation

RS and RSRs showed positive correlation with TAPSE (p. value < 0.001 and < 0.001 respectively) and FAC (p. value < 0.001 and < 0.001 respectively). While they showed negative correlation with age (p. value 0.001 and < 0.001 respectively), LA diameter

(p. value 0.007 and 0.014 respectively) and SPAP (p. value 0.004 with gender, LV EF, Tri S` and Tri E/A (Figures 16 and 17). and 0.003 respectively). And showed no significant correlation

Table 4: Right ventricular tissue Doppler echocardiographic parameters.

Parameter		Patients	Controls	P. value
Tri S` (m/s)	Range	0.11 - 0.30	0.10 - 0.28	0.002*
	Mean ± SD	0.20 ± 0.06	0.16 ± 0.05	
Tri E` (m/s)	Range	0.05 - 0.27	0.09 - 0.26	0.142
	Mean ± SD	0.13 ± 0.05	0.15 ± 0.06	
Tri A` (m/s)	Range	0.11 - 0.37	0.11 - 0.24	0.193
	Mean ± SD	0.20 ± 0.07	0.18 ± 0.04	
Tri E`/A`	Range	0.22 - 1.17	0.38 - 1.77	0.001*
	Mean ± SD	0.68 ± 0.20	0.94 ± 0.46	
Tri E/E`	Range	1.48 - 10	2.04 - 5.33	0.052
	Mean ± SD	4.4 ± 1.64	3.61 ± 1.02	

Tri S`: Peak Systolic Velocity Of Tricuspid Valve Annulus; Tri E`: Peak Early Diastolic Velocity Of Tricuspid Valve Annulus; Tri A`: Peak Late Diastolic Velocity Of Tricuspid Valve Annulus; Tri E`/A`: Tricuspid Valve E`/A` Ratio; Tri E/E`: Tricuspid Valve E/E` Ratio; SD: Standard Deviation. * Significant: p < 0.05

Table 5: Right ventricular speckle tracking echocardiographic parameters.

Parameter		Patients	Controls	P. value
RS (E %)	Range	-14.99 – -30.8	-24.37 – -36.97	< 0.001*
	Mean ± SD	-22.9 ± 4.7	-30.67 ± 3.9	
RSRs (s ⁻¹)	Range	-1.23 – -1.96	-1.52 – -2.3	< 0.001*
	Mean ± SD	-1.6 ± 0.22	-1.91 ± 0.24	
RSRe (s ⁻¹)	Range	-1.13 – -2.22	-1.5 – -2.78	< 0.001*
	Mean ± SD	-1.68 ± 0.32	-2.14 ± 0.4	
RSRa (s ⁻¹)	Range	-0.92 – -1.92	-1.15 – -2.31	< 0.001*
	Mean ± SD	-1.42 ± 0.3	-1.73 ± 0.36	

RS (E %): Right Ventricular Peak Systolic Longitudinal Strain; RSRs (s⁻¹): Right Ventricular Peak Systolic Strain Rate; RSRe (s⁻¹): Right Ventricular Peak Early Diastolic Strain Rate; RSRa (s⁻¹): Right Ventricular Peak Late Diastolic Strain Rate; SD: Standard Deviation. * Significant: p < 0.05.

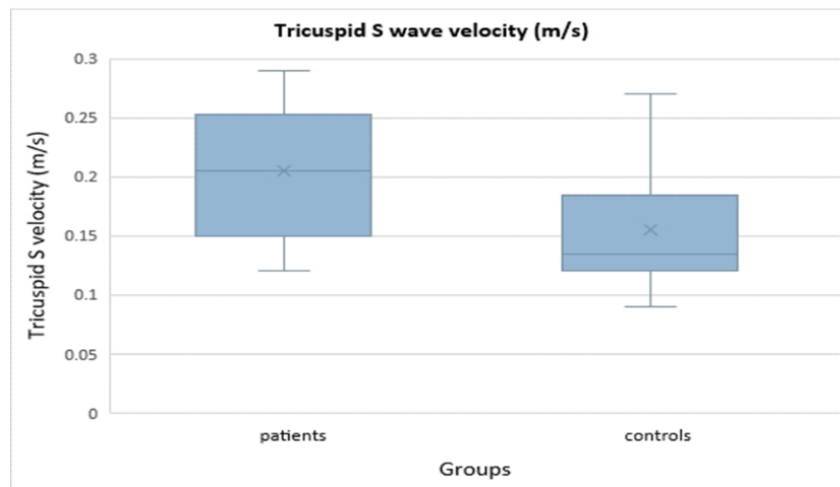


Figure 11: Comparison of the peak systolic velocity of tricuspid valve annulus (Tri S`) between the two study groups.

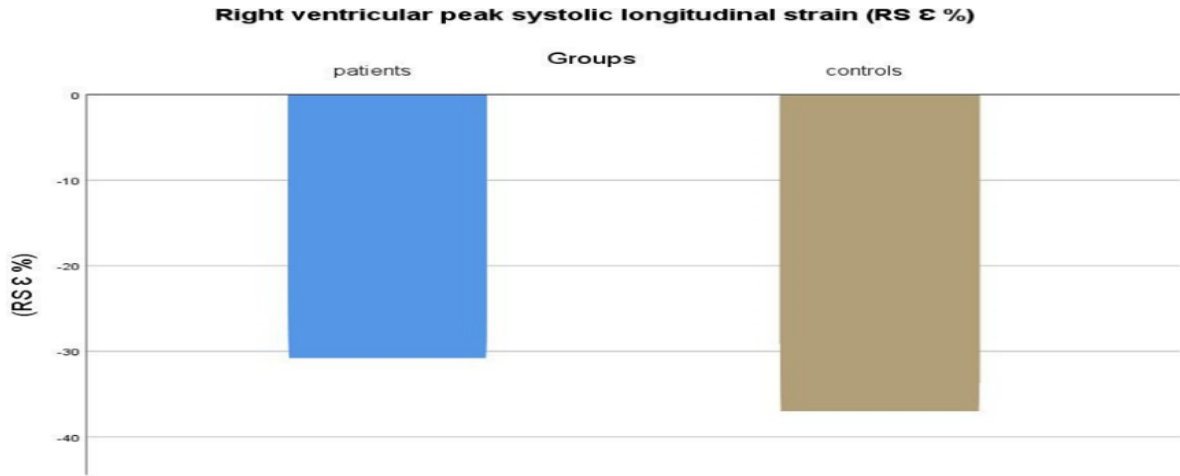


Figure 12: Comparison of right ventricular peak systolic longitudinal strain (RS ϵ %) between the two study groups.

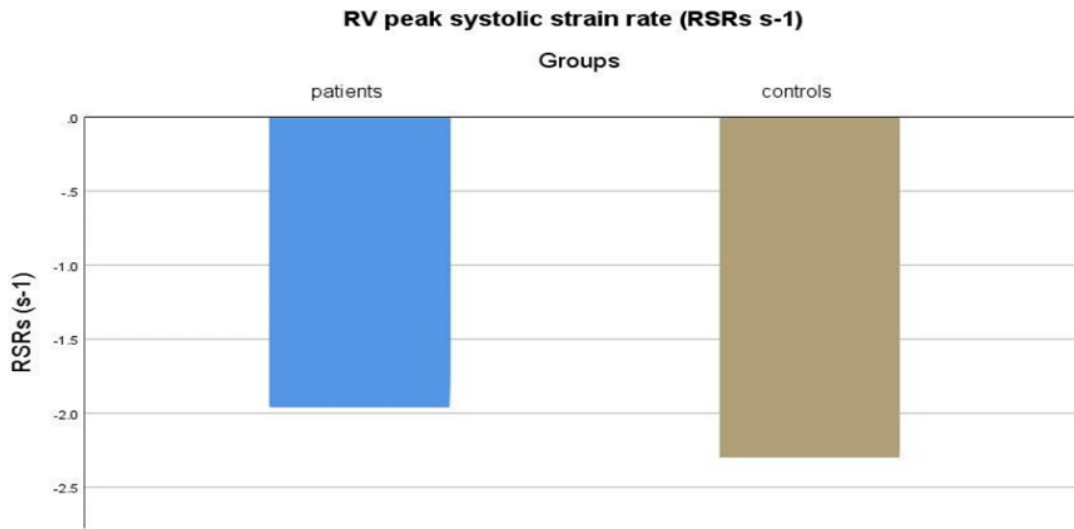


Figure 13: Comparison of right ventricular peak systolic longitudinal strain rate (RSRs s^{-1}) between the two study groups.

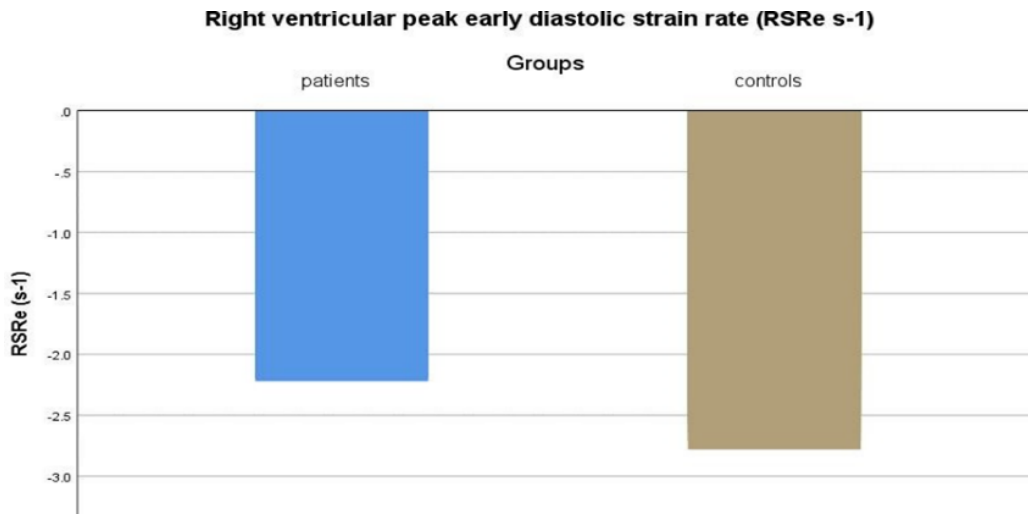


Figure 14: Comparison of right ventricular peak early diastolic strain rate (RSRe s^{-1}) between the two study groups.

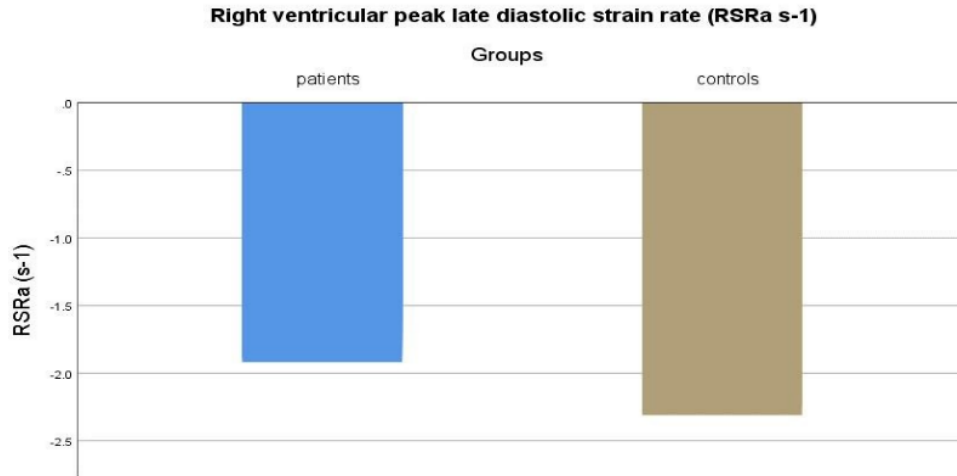


Figure 15: Comparison of right ventricular peak late diastolic strain rate (RSRa s^{-1}) between the two study groups.

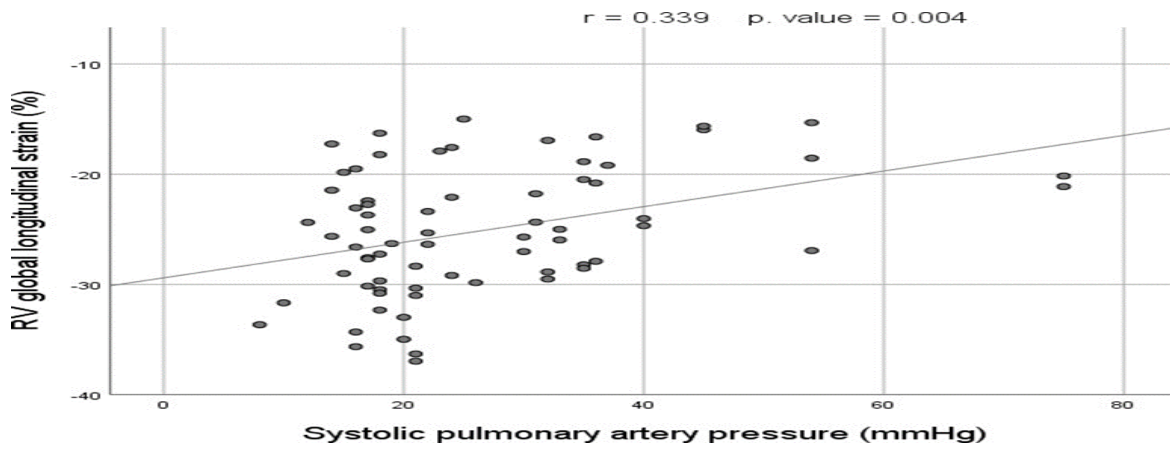


Figure 16: Correlation between right ventricular global longitudinal strain and SPAP.

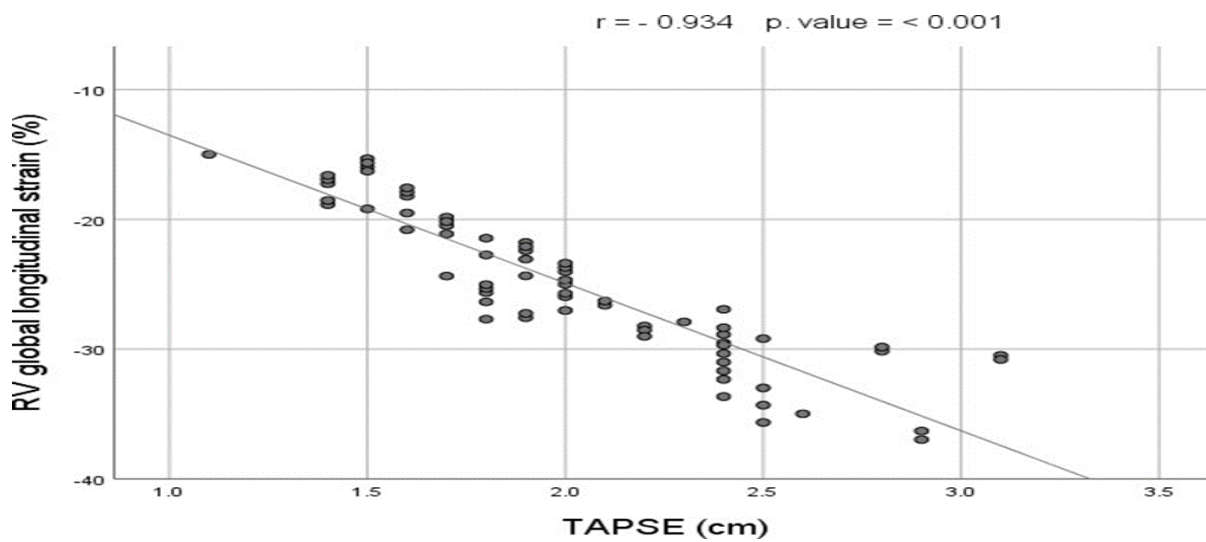


Figure 17: Correlation between right ventricular global longitudinal strain and TAPSE.

Discussion

Cardiovascular disease is the leading cause of mortality in patients undergoing haemodialysis, accounting for 50% of deaths. In particular, congestive heart failure is the most common finding in these patients and is associated with a poor prognosis. HD which is usually carried out through a surgically-created arteriovenous fistula has been associated with an increased risk of PHT. This fistula causes a left- to-right shunt leading to volume overload. Most of the available studies focused on left ventricular function in dialysis patients, while the impact of dialysis and its related medications on the development of right ventricular dysfunction has not fully been investigated. Previous studies concerning RV function in HD patients revealed a marked deterioration with long-standing dialysis. These studies mainly used conventional echocardiographic variables such as TAPSE, FAC and myocardial performance index (MPI). While this study added speckle tracking modality as a sensitive tool in the assessment of RV function [15,16].

Characteristics of the study population

In our study, there was no statistically significant difference between the two groups regarding age and sex (p. value 0.279 and 0.945 respectively) (Table 1). And this was similar to said et al. who performed a tissue Doppler study to evaluate right ventricular function in patients with ESRD starting dialysis, and found no difference between the two groups regarding age and sex (p. value 0.184 and 0.52 respectively) [17]. In our study, there was a significant increase in the prevalence of hypertension in HD group (44% of cases) in comparison with control group (no cases) with a (p. value 0.001). And this was similar to Sun et al. who studied the long-term impact of HD on the RV assessed via three-dimensional STE, and found a significant increase in blood pressure in HD patients (p. value < 0.001) [18]. In our study, diabetes mellitus was significantly increased in HD patients (46% of cases) in comparison with controls (no cases) with a (p. value 0.001). And this was similar to Ali et al. who assessed left and right ventricular functions in HD versus recently diagnosed uremic patients with preserved systolic function, and found that HD patients had a significantly higher percent of DM (p. value 0.003). But these results were discordant with Paneni et al. and Momtaz et al. who found no difference between HD patients and controls regarding DM (p. value 0.81 and 0.637 respectively) [19,20].

Left side echocardiographic parameters

In our study, there was no significant difference between the two groups regarding aortic diameter (p. value 0.193) (Table 2). And this was similar to Momtaz et al. who studied RV dysfunction in

patients with ESRD on regular HD, and also found no significant difference between HD patients and controls regarding aortic diameter (p. value 0.262) [5].

In our study, HD patients showed significant increase in left atrial diameter in comparison with controls (mean 3.84 cm \pm SD 0.53 vs. 3.38 \pm SD 0.41 respectively, p. value < 0.001) (Figure 7). And this was similar to Karavelioğlu et al. who assessed RV function in nondiabetic normotensive HD patients, and also found a significant increase in LA diameter in HD group (mean 3.41 cm \pm SD 0.5 vs. 3.19 cm \pm SD 0.44 respectively, p. value 0.001). In our study, HD patients showed a significant increase in both IVSd (mean 0.88 cm \pm SD 0.2 vs. 0.65 cm \pm SD 0.15 respectively, p. value 0.001) and LVPWTd (mean 1.31 cm \pm SD 0.25 vs. 0.91 cm \pm SD 0.22 respectively, p. value < 0.001) in comparison with controls. And this was similar to Ardahanli et al. who also found a significant increase in IVSd (mean 1.41 cm \pm SD 0.38 vs. 0.97 cm \pm SD 0.19, p. value < 0.001) and LV PWTd (mean 1.32 cm \pm SD 0.29 vs. 0.93 cm \pm SD 0.16 respectively, p. value < 0.001). In our study, there was no significant difference between the two groups regarding LVEDD and LVESD (p. value 0.219 and 0.845 respectively). And this was similar to Said et al. who also found no difference in the LVEDD and LVESD between HD patients and controls (p. value 0.7 and 0.34 respectively) [21].

In our study, there was no significant difference between the two groups regarding LV EF (p. value 0.246). And this was similar to Said et al. who also found no difference in the LV EF between HD and control groups (p. value 0.525). However, Paneni et al. found that EF was significantly lower in HD patients than in peritoneal dialysis patients and controls (mean 56.1% \pm SD 8.6 vs. mean 62.4% \pm SD 9.81, and mean 68.3% \pm SD 5.7 respectively, p. value 0.001). This difference can be explained by the relatively shorter duration of dialysis in the current study than that in the study.

Right side echocardiographic parameters

In our study, there was no significant difference between the two groups regarding Tri E (p. value 0.818) (Table 3). And this was similar to Ardahanli et al. who also found no difference in Tri E between HD and control groups (mean 0.59 m/s \pm SD 0.21 vs. mean 0.62 m/s \pm SD 0.22 respectively, p. value 0.523). However, Karavelioğlu et al. found that HD patients had significantly lower values than controls (mean 0.5 m/s \pm SD 0.95 vs. mean 0.56 m/s \pm SD 0.95 respectively, p. value 0.007). In our study, Tri A was significantly increased in HD patients in comparison with controls (mean 0.63 m/s \pm SD 0.17 vs. mean 0.51 m/s \pm SD 0.13 respectively, p. value 0.006). And this was similar to Ardahanli et al. who also found a significant increase in Tri A in HD patients

in comparison with controls (mean $0.63 \text{ m/s} \pm \text{SD } 0.27$ vs. mean $0.45 \text{ m/s} \pm \text{SD } 0.26$ respectively, p . value < 0.001).

In our study, Tri E/A was significantly decreased in HD patients in comparison with controls (mean $0.89 \pm \text{SD } 0.38$ vs. mean $1.05 \pm \text{SD } 0.36$ respectively, p . value 0.013). And this was similar to Ardahanli et al. who also found a significant decrease in the Tri E/A in HD patients in comparison with controls (mean $0.93 \pm \text{SD } 0.25$ vs. mean $1.37 \pm \text{SD } 0.24$ respectively, p . value < 0.001). In our study, HD patients showed a statistically significant decrease in FAC in comparison with controls (mean $41.7\% \pm \text{SD } 6.3$ vs. $47.2\% \pm \text{SD } 4.5$ respectively, p . value < 0.001) (Figure 2). And this was similar to Momtaz et al. and Karavelioğlu et al. who also found that FAC was significantly lower in HD patients in comparison with controls (mean $37.54\% \pm \text{SD } 9.86$ vs. $43.5\% \pm \text{SD } 4.8$ respectively, p . value < 0.001) and (mean $40.1\% \pm \text{SD } 7.7$ vs. $48.4\% \pm \text{SD } 9.9$ respectively, p . value < 0.001) respectively. In our study, HD patients showed a significant decrease in TAPSE in comparison with controls (mean $1.9 \text{ cm} \pm \text{SD } 0.45$ vs. $2.31 \text{ cm} \pm \text{SD } 0.35$ respectively, p . value < 0.001) (Figure 1). And this was similar to Karavelioğlu et al. and Ardahanli et al. who also found that TAPSE was significantly lower in HD patients in comparison with controls (mean $2.32 \text{ cm} \pm \text{SD } 0.42$ vs. $2.56 \text{ cm} \pm \text{SD } 0.29$ respectively, p . value 0.003) and (mean $1.61 \text{ cm} \pm \text{SD } 0.35$ vs. $2.09 \text{ cm} \pm \text{SD } 0.27$ respectively, p . value < 0.001) respectively. In our study, HD patients showed a statistically significant increase in SPAP in comparison with controls (mean $29.6 \text{ mmHg} \pm \text{SD } 14.5$ vs. $18.7 \text{ mmHg} \pm \text{SD } 5.46$ respectively, p . value 0.002) (Figure 3). And this was similar to Momtaz et al., Sun et al. and Ardahanli et al. who also detected an increase in SPAP among HD population in comparison with controls (mean $32.75 \text{ mmHg} \pm \text{SD } 10.11$ vs. $25.23 \text{ mmHg} \pm \text{SD } 3.99$ respectively, p . value < 0.001), (mean $35.1 \text{ mmHg} \pm \text{SD } 8.1$ vs. $29.6 \text{ mmHg} \pm \text{SD } 2.9$ respectively, p . value 0.029) and (mean $37.4 \text{ mmHg} \pm \text{SD } 8.3$ vs. $19 \text{ mmHg} \pm \text{SD } 6.8$ respectively, p . value < 0.001) respectively.

Right side tissue doppler parameters

In our study, haemodialysis patients showed a significant decrease in Tri S` in comparison with controls (mean $0.20 \text{ m/s} \pm \text{SD } 0.06$ vs. $0.16 \text{ m/s} \pm \text{SD } 0.05$ respectively, p . value 0.002) (Figure 4) (Table 4). And this was similar to Momtaz et al. and Paneni et al. who also found that HD patients had lower Tri S` in comparison with controls (mean $0.12 \text{ m/s} \pm \text{SD } 0.03$ vs. $0.16 \text{ m/s} \pm \text{SD } 0.04$ respectively, p . value < 0.001) and (mean $0.17 \text{ m/s} \pm \text{SD } 0.02$ vs. $0.13 \text{ m/s} \pm \text{SD } 0.03$ respectively, p . Value < 0.001) respectively. In our study, there was no significant difference between the two groups regarding Tri E` (p . value 0.142) [22]. And these results were discordant with Karavelioğlu et al. and Ali et al. who found a significant decrease in Tri E` of HD patients in comparison with controls (p . value < 0.001 and 0.028

respectively). In our study, there was no significant difference between the two groups regarding Tri A` (p . value 0.193). And this was similar to Karavelioğlu et al. and Ali et al. who also found no statistically significant difference between the two groups regarding Tri A` (p . value 0.336 and 0.764 respectively). In our study, HD patients showed a statistically significant decrease in Tri E`/A` in comparison with controls (mean $0.68 \pm \text{SD } 0.2$ vs. $0.94 \pm \text{SD } 0.46$ respectively, p . value 0.001). And this was similar to Karavelioğlu et al. who also found a significant decrease in Tri E`/A` in HD patients in comparison with controls (mean $0.59 \pm \text{SD } 0.29$ vs. 1.19 ± 1.67 respectively, p . value 0.034). In our study, there was no significant difference between the two groups regarding Tri E/E` (mean $4.4 \pm \text{SD } 1.64$ vs. $3.61 \pm \text{SD } 1.02$ respectively, p . value 0.052). And this was similar to Sun et al. who also found no significant difference between the two groups regarding Tri E/E` (mean $4.0 \pm \text{SD } 1.8$ vs. mean $3.5 \pm \text{SD } 2.1$ respectively, p . value 0.2). However, Karavelioğlu et al. found that HD patients had significantly higher values than controls (mean $7.6 \pm \text{SD } 4.0$ vs. mean $5.0 \pm \text{SD } 1.4$ respectively, p . value 0.005).

Right ventricular speckle tracking parameters

In our study, HD patients showed a statistically significant decrease in RV peak systolic strain (RS) in comparison with controls (mean $-22.9\% \pm \text{SD } 4.7$ vs. mean $-30.67\% \pm \text{SD } 3.9$ respectively, p . value < 0.001) (Figure 12) (Table 5). And this was similar to Tamulénaitė et al. who studied changes of left and right ventricle mechanics and function in patients with ESRD undergoing HD, and also found a significant decrease in RS in HD patients in comparison with controls (mean $-22.96\% \pm \text{SD } 3.04$ vs. $-25.45\% \pm \text{SD } 2.48$ respectively, p . value < 0.001). In the same way, Sun et al. also found a decrease in RS in HD patients compared to controls (mean $-23.4\% \pm \text{SD } 4.7$ vs. $-27.7\% \pm \text{SD } 4.0$ respectively, p . value < 0.001). Fukuda et al. who studied RV free wall speckle tracking strain for evaluation of RV performance in patients with PHT also found decreased RS in PHT patients compared to controls (mean $-19.8\% \pm \text{SD } 6.9$ vs. $-25.8\% \pm \text{SD } 5.2$ respectively, p . value < 0.005). Also, Li et al. who studied RV longitudinal strain by 2D STE found similar results (mean $-17.22\% \pm \text{SD } 4.18$ vs. $-12.64\% \pm \text{SD } 3.23$ respectively, p . value < 0.001). And similarly, Brand et al. who studied right heart function in impaired LV diastolic function, found a reduced RS in patients with diastolic dysfunction compared to patients with normal diastolic function (mean $-23.9\% \pm \text{SD } 5.5$ vs. $-26.7\% \pm \text{SD } 5.6$ respectively, p . value 0.005). In our study, HD patients showed a statistically significant decrease in peak systolic strain rate (RSRs) in comparison with controls (mean $-1.60 \text{ s}^{-1} \pm \text{SD } 0.22$ vs. $-1.91 \text{ s}^{-1} \pm \text{SD } 0.24$ respectively, p . value < 0.001) (Figure 13). And this was similar to Luo et al. who studied RV function in systemic lupus

erythematous patients with and without PHT and also found a significant decrease in RSRs in PHT patients compared to controls (mean $-1.58 \text{ s}^{-1} \pm \text{SD } 0.38$ vs. $-1.88 \text{ s}^{-1} \pm \text{SD } 0.40$ respectively, p . value < 0.001). Also, Sachdev et al. who studied RV strain to predict survival in patients with PHT, found a significant decrease in RSRs in PHT patients and was associated with higher rates of morbidity and mortality (mean $-0.87 \text{ s}^{-1} \pm \text{SD } 0.43$). In our study, HD patients showed a significant decrease in peak early diastolic strain rate (RSRe) and peak late diastolic strain rate (RSRa) in comparison with controls (mean $-1.68 \text{ s}^{-1} \pm \text{SD } 0.32$ vs. $-2.14 \text{ s}^{-1} \pm \text{SD } 0.40$ respectively, p . value < 0.001) (Figure 14) and (mean $-1.42 \text{ s}^{-1} \pm \text{SD } 0.30$ vs. $-1.73 \text{ s}^{-1} \pm \text{SD } 0.36$ respectively, p . value < 0.001) (Figure 15) respectively. And this was similar to Luo et al. who also found a significant decrease in RSRe and RSRa in PHT patients compared to controls (mean $-1.67 \text{ s}^{-1} \pm \text{SD } 0.56$ vs. $-2.11 \text{ s}^{-1} \pm \text{SD } 0.67$ respectively, p . value < 0.001) and (mean $-1.44 \text{ s}^{-1} \pm \text{SD } 0.51$ vs. $-1.70 \text{ s}^{-1} \pm \text{SD } 0.61$ respectively, p . value < 0.001) respectively [23-27].

Study Limitations

The number of patients included in our study was relatively small, however, the results were quite comparable to larger studies. The study was of a cross-sectional design, which limits interpretation of the results with respect to cause and effect. Also, the study included subjects with different onset, severity and treatment modalities of CRF which may have a potential influence on the results. Echocardiographic measurements were not done at the same cardiac cycle; but careful consideration was taken to obtain measurements at cycles with a nearly equal R-R interval. Additionally, our results were based only on 2D echocardiographic technique which is inferior to 3D echocardiography or magnetic resonance imaging-based measurements. Additionally, STE needs image acquisition with high technical quality which is not always possible in the clinical setting. Finally, accurate estimation of the volume status pre- and post-dialysis was not done. So, further studies are required.

Conclusion

HD patients had a significant increase in the prevalence of cardiovascular risk factors such as HTN and DM. They also had impaired RV systolic function, as evidenced by decreased TAPSE, FAC and Tri S'. And impaired diastolic function, as evidenced by decreased tricuspid E/A ratio, E'/A' ratio and increased tricuspid A wave velocity. They also had higher incidence of LVH and increased LA diameter, which are associated with LV diastolic dysfunction. Additionally, they had increased incidence of PHT. And finally, they have decreased RV strain and strain rate values.

RV strain and strain rate showed positive correlation with TAPSE and FAC, and negative correlation with age, LA diameter and SPAP. Speckle tracking echocardiography is an emerging new technique that can be used for early detection and follow up of RV dysfunction in HD patients, as it has the advantage of detecting early and subclinical changes.

Declaration of Conflicting Interests

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