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Original Article

Immediate Effect of Hemodialysis on Left Ventricular Functions of Patient with End Stage Renal Diseases Assessed by Three-Dimensional Echocardiography

Mohammed Ali Abdulhammid *, Wael Mohamed Atia, Fouad Rafik Amin

Department of Cardiology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

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*Corresponding author

Email: mhd01017145474@gmail.com

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ABSTRACT

Background: Patients with end stage renal disease under hemodialysis are at increased risk for morbidities and mortality. Cardiovascular diseases are independent risk for death among those patients. Echocardiography is a non-invasive method that helps identification of the problem and risk stratification.

Aim of the work: The study aimed to determine whether left ventricular function differs in pre-dialytic compared with post-dialytic periods, and to recognize relationship between hemodialysis and left ventricular function.

Patients and Methods: Patients undergoing hemodialysis in the duration between August 2022 and February 2023 in Alhussein University Hospitals were eligible to participate. They underwent echocardiographic assessment in 2 times; pre- and immediately after dialysis session.

Results: Fifty patients undergoing regular hemodialysis were recruited in the study. Their mean age was 48.92 ± 6.93 years old. 70% of patients [35 patients] were males. All patients were hypertensive, while 46% of them [23 patients] were diabetic. We found that there was a slight improvement of both systolic and diastolic functions assessed by M-mode, Simpson method, 3D and Doppler study. however, none of this improvement was statistically significant.

Conclusion: No significant change in both cardiac structure and function can occur immediately after the dialysis sessions. That is why longer follow up period is recommended for future research.

Keywords: 3D echocardiography; Left ventricular function; Hemodialysis; End Stage Renal Disease.

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INTRODUCTION

In individuals with chronic kidney disease [CKD], cardiovascular disease [CVD] is considered a leading cause of death and disability. Reduction in estimated glomerular filtration rate [eGFR] is an independent predictor of death, cardiovascular disease, and prolonged hospitalization [1].

End-stage renal disease [ESRD] is also known for high mortality, even though dialysis treatment and patient care have improved greatly in recent decades. Traditional cardiovascular risk factors, such as hyper-tension, diabetes mellitus, and dyslipidemia; nontraditional factors, such as malnutrition, and oxidative stress; and CKD-related risk factors, such as atherosclerosis, anemia, and altered calcium phosphate metabolism; are all potential causes of a poor prognosis in CKD patients [2]. Thus, physicians should be able to improve outcomes by identifying high-risk patients early and adjusting treatment accordingly. For assessing cardiac morphology [such as left ventricle [LV] volume and mass] and function [such as ejection fraction [EF] and cardiac output], cardiac magnetic resonance imaging [cMRI] is now universally acknowledged as the gold standard among noninvasive imaging techniques [3].

On the other hand, cMRI has a number of significant drawbacks that make it impractical to use in clinical settings, including its prohibitive price tag, inability to be transported easily, and lack of predictive data for a number of CVDs. Its therapeutic usefulness is therefore limited by these considerations. Gadolinium toxicity is uncommon in individuals with severe CKD, although nephrogenic systemic fibrosis remains a key cause for its limitation in clinical application [4]. Thus, the heart's structure and function can be assessed by echocardiography. The accuracy of echocardiographic readings is operator dependent. However, it has been shown to be highly connected with histologic results and has been well verified in epidemiological research over the last several years. Consequently, echocardiographic studies may play a pivotal role in determining the efficacy of therapeutic drugs, classifying prognostic risk factors, and evaluating cardiac function [5].

There is a scarce evidence assessing the direct relation between HD sessions and cardiac condition improvement among patients undergoing hemodialysis. That is why we tried to conduct this study.

The objective of this research was to determine whether left ventricular function differs in predialytic compared with post-dialytic, and to identify relationship between hemodialysis and left ventricular function.

PATIENTS AND METHODS

An observational study was conducted in Alhussein University hospitals in the duration between August 2022 and February 2023. Patients suffering from ESKD undergoing regular hemodialysis were eligible to participate in the study. Chronic kidney disease was defined according to the recent guidelines established by Kidney disease improving global outcomes organization [KDIGO] published in 2012 [6].

Table [1]: Classification of CKD stages according to estimated GFR [6]

GFR stages	GFR [ml / min / 1.73 m^2]	Interpretation
G1	>90	Normal
G2	60 – 89	Mildly decreased
G3a	45 – 59	Mild to moderate decrease
G3b	30 – 44	Moderate to severe decrease
G4	15 – 29	Severe decrease
G5	<15	ESKD

An informed consent was obtained from all participants before enrollment in the study. Complete history was taken from all participants with special emphasis on age, gender associated comorbidities; hypertension, diabetes mellitus and special habits. Resting ECG was done for all patients.

The Inclusion criteria: Patients from both genders between 40 and 65 years old undergoing regular hemodialysis sessions for a duration more than 2 years.

The Exclusion criteria: Patients with a confirmed diagnosis of heart failure were excluded from the study. Patients known to have CVD as congenital, valvular, cardiomyopathy or atrial fibrillation were also excluded.

Echocardiography: All patients were subjected to echocardiographic assessment in 2 times; immediately before initiation and after dialysis session completion. All echocardiography assessments were performed by a single operator using a commercial echocardiography system [Vivid E95, GE Healthcare, Horten, Norway] with a wide bandwidth [1.4-5.2 MHz] matrix-array transducer [4Vc-D, GE Healthcare, Horten, Norway]. With all patients being in left decubitus position. The left ventricular analysis was done according to the recommendations published by European Association of Cardiovascular Imaging [EACVI] and the American Society of Echocardiography [ASE] [7]. The left ventricular end diastolic dimensions were measured from the parasternal long-axis view. Peak early [E] and late [A] diastolic velocity and the E/A ratio were assessed from the mitral flow velocity pattern with the pulse Doppler method. Average peak early diastolic velocity of mitral valve annulus [e′] were obtained from the septal and lateral sides of the mitral annulus in the apical four-chamber view with Doppler tissue imaging. The E/e′ ratio was calculated to estimate LV filling pressures. LV diastolic function was evaluated from E/A ratio, E/e´. E/A ratio <0.75, or >1.8 was labeled as LV diastolic dysfunction. Real-Time 3D echocardiographic imaging was performed from the cardiac apex by single beat acquisition or multi-beat acquisition [triggered by ECG] using 2 to 3 consecutive cardiac cycles during a single breath-hold. Resolution and frame rate were optimized by adjusting the depth and the sector width while including entire LV cavity within the pyramidal volume. From the recorded real-time 3D images, end-systolic and end diastolic LV volumes and ejection fraction. By indexing left ventricular end diastolic volume [EDV] to body surface area [BSA], LV dilatation was defined according to the ASE/EACVI guidelines recommendation for 3D echocardiographic LV volumes measurement as follows: upper limits of LV EDV 79 ml/m2 for men and 71 ml/m2 for women [7].

Statistical analysis: We analyzed the data using Statistical package for social sciences [SPSS] software version 24 for windows. Numerical data was described in terms of means and standard deviations if normally distributed. Kolmogrov-semornov test was used to test the normality of distribution of numerical variables. Categorical data was described in terms of frequencies and percentages. Chi square test was used to test the association between categorical data. Fissure exact test was used in case of violation of the assumptions. Paired sample t test was used to test the association between paired numerical variables if normally distributed. P value less than 0.05 was considered statistically significant.

RESULTS

Fifty patients with ESRD undergoing regular hemodialysis were recruited to participate in the study. Their mean age was 48.9 ± 6.9 years old. 30 % of patients [15 patients] were females. All patients were suffering from hypertension and all patients in sinus rhythm. While 46% of them were diabetic [23 patients]. Forty percent of patients [20 patients] were active smokers. We also found that 52% of patients [26 patients] had family history of IHD [Table 2].

The cardiac status of all patients was evaluated using echocardiography just before the dialysis sessions using M-mode, biplane mode, A2c mode, A4c mode, and 3-dimensional method and revealed that there was a slight improvement in EF post dialysis [P=0.157]. however, there was a slight decrease in ESV from 51.56 ± 20.09 to 50.1 ± 22.67 ml, p=0.056 detected by m mode. We also found a slight improvement of cardiac dimensions post dialysis; there was a slight decrease in ESD from 2.99 ± 0.47 to 2.93 ± 0.49 cm, p=0.541. however, there was a slight decline in EDD from 5.01 ± 0.76 to 4.97 ± 0.75 cm. however, this was statistically insignificant [p=0.078]. Regarding both left atrium and aortic root, we found that there was a slight decrease in left atrial dimensions from 3.54 ± 0.47 to 3.51 ± 0.46 cm, p=0.061. on the other hand, the aortic root dimensions were not significantly affected by hemodialysis, p =0.533 as shown in table [3].

We also used biplane technique to evaluate the cardiac parameters and found that there was a slight increase in EF from 60.78 ± 6.23 to 61.76 ± 5.35, P=0.523. On the other hand, there was a slight decrease in both ESV and EDV from [59.6 ± 21.93 to 57.36 ± 21.48, and from 133.46 ± 41.8 to 132.36 ± 39.64] respectively. However, this was statistically insignificant [p=0.095, p=0.127] as shown in table [4].

We also used A2C technique to evaluate the cardiac parameters and found that there was a slight increase in EF from 62.16 ± 5.05 to 63.96 ± 5.64, P=0.097. On the other hand, there was a slight decrease in both ESV and EDV from [60.5 ± 27.08 to 59.48 ± 23.67, and from 137.7 ± 46.4 to 136.7 ± 44.16, P=0.418, p=0.058] respectively as shown in table [5].

We also used A4C technique to evaluate the cardiac parameters and found that there was a slight increase in EF from 61.18 ± 5.84 to 62.8 ± 5.36, P=0.157. On the other hand, there was a slight decrease in ESV from [54.42 ± 21.2 to 53.68 ± 20.4, p = 0.072], while there was a slight increase in EDV from 119.78 ± 38.3 to 121.8 ± 35.9, p=0.078] respectively [table 6].

We also used 3D technique to evaluate the cardiac parameters and found that there was a slight increase in EF from 6**4** ± 5.75 to 64.19 ± 5.1, P = 0.562. On the other hand, there was a slight decrease in ESV from [58.32 ± 17.32 to 57.54 ± 16.72, p = 0.865], while the decline of EDV from 140.3 ± 39.08 to 139.8 ± 39.19 was not statistically significant [p=0.550] [table 7].

We also assessed the diastolic dysfunction parameters and found that there was a slight decrease in both E/A ratio and E/e ratio [p=0.057, p=0.627] respectively. However, there was a slight increase in lateral e post dialysis, but this was statistically insignificant [p=0.514] as shown in table [8].

Table [2]: Sociodemographic characteristics of included patients [n=50]

Variable		Findings
Age [years], Mean ± SD		48.92 ± 6.93
Gender	Males Females	35 [70] 15 [30]
Diabetes mellitus		23 [46]
Smoker		20 [40]
Cardiac family history		26 [52]

Table [3]: Association between pre and post dialysis cardiac parameters assessed by M mode

M mode	Pre dialysis	Post dialysis	P value*
EF	64.46 ± 5.69	65.06 ± 5.49	0.157
ESV	**51**.56 ± 20.09	50.1 ± 22.67	0.056
EDV	131.16 ± 41.26	133.6 ± 44.5	0.087
ESD	2.99 ± 0.47	2.93 ± 0.49	0.541
EDD	5.01 ± 0.76	4.97 ± 0.75	0.078
LA	3.54 ± 0.47	3.51 ± 0.46	0.061
Aor	3 ± 0.64	3.01 ± 0.64	0.533

* Paired sample t test, EF; Ejection fraction. ESV; End systolic volume, EDV; End diastolic volume, ESD; End systolic dimensions, EDD; End diastolic dimensions, LA; left atrium, Aor; Aortic root.

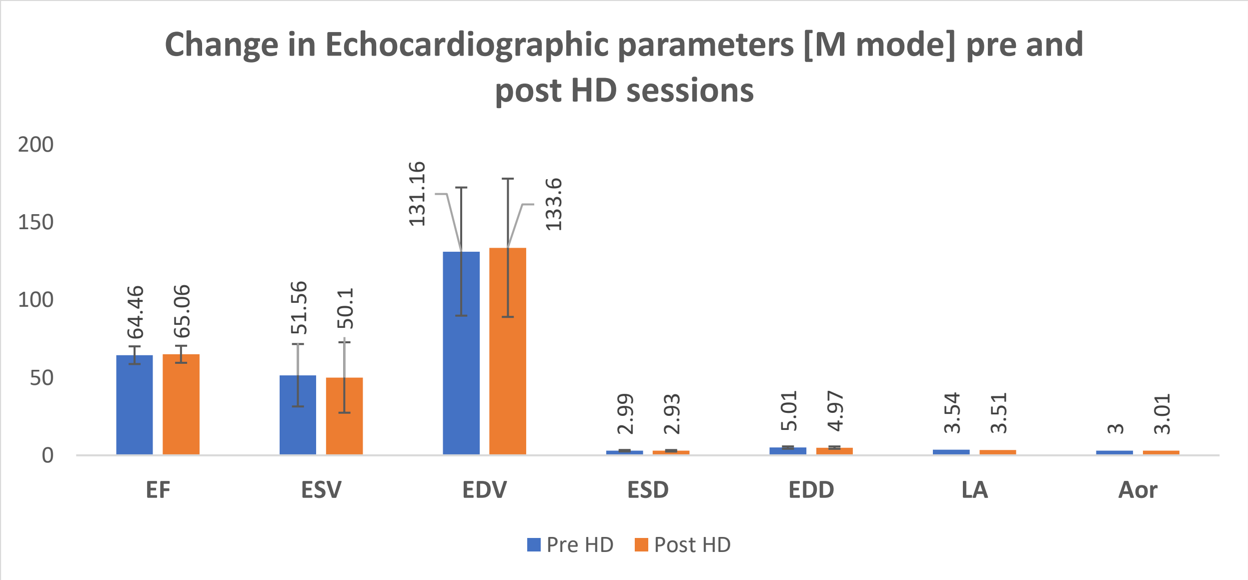

Figure [1]: Difference between pre and post dialysis regarding left ventricular systolic function using M mode echocardiography

Table [4]: Association between pre and post dialysis cardiac parameters assessed by Biplane method

Biplane method	Pre dialysis	Post dialysis	P value*
EF	60.78 ± 6.23	61.76 ± 5.35	0.523
ESV	59.6 ± 21.93	57.36 ± 21.48	0.095
EDV	133.46 ± 41.8	132.36 ± 39.64	0.127

* Paired sample t test, EF; Ejection fraction. ESV; End systolic volume, EDV; End diastolic volume.

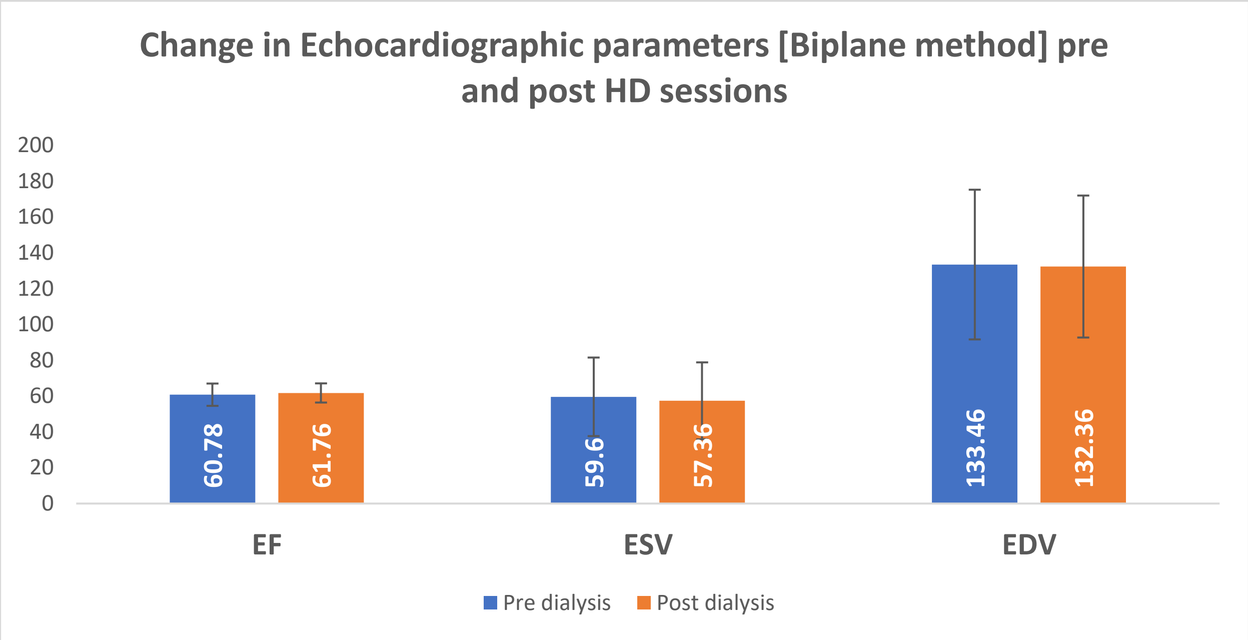

Figure [2]: Difference between pre and post dialysis regarding left ventricular systolic function using biplane echocardiography

Table [5]: Association between pre and post dialysis cardiac parameters assessed by A2C method

A2C method	Pre dialysis	Post dialysis	P value*
EF	62.16 ± 5.05	63.96 ± 5.64	0.097
ESV	60.5 ± 27.08	59.48 ± 23.67	0.418
EDV	137.7 ± 46.4	136.7 ± 44.16	0.058

* Paired sample t test, EF; Ejection fraction. ESV; End systolic volume, EDV; End diastolic volume.

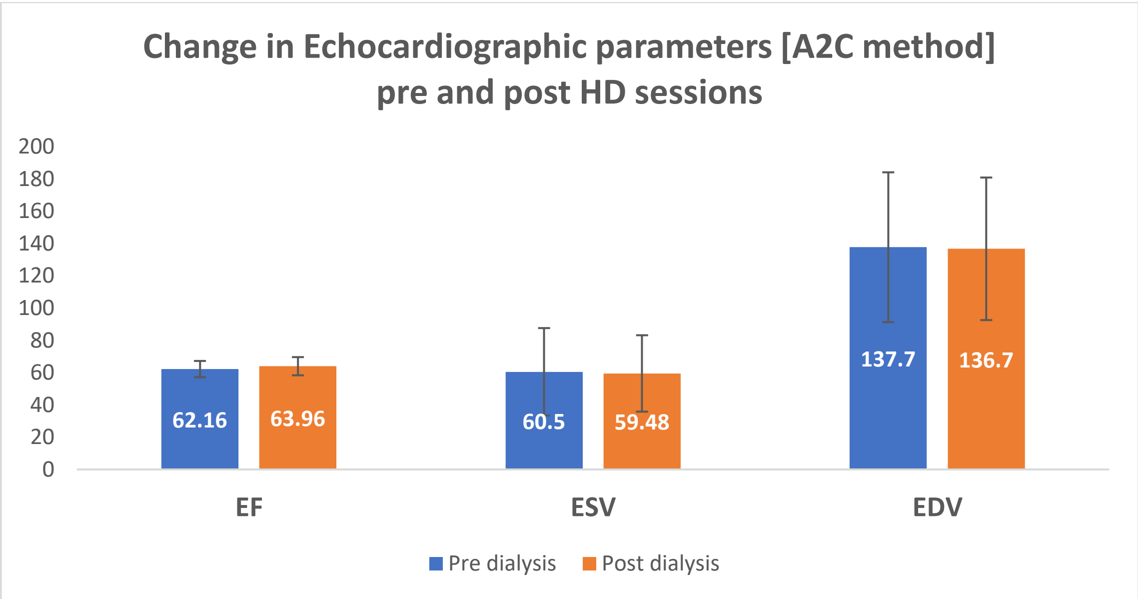

Figure [3]: Difference between pre and post dialysis regarding left ventricular systolic function using A2C echocardiography

Table [6]: Association between pre and post dialysis cardiac parameters assessed by A4C method

A4C method	Pre dialysis	Post dialysis	P value*
EF	61.18 ± 5.84	62.8 ± 5.36	0.157
ESV	54.42 ± 21.2	53.68 ± 20.4	0.072
EDV	119.78 ± 38.3	121.8 ± 35.9	0.078

* Paired sample t test, EF; Ejection fraction. ESV; End systolic volume, EDV; End diastolic volume

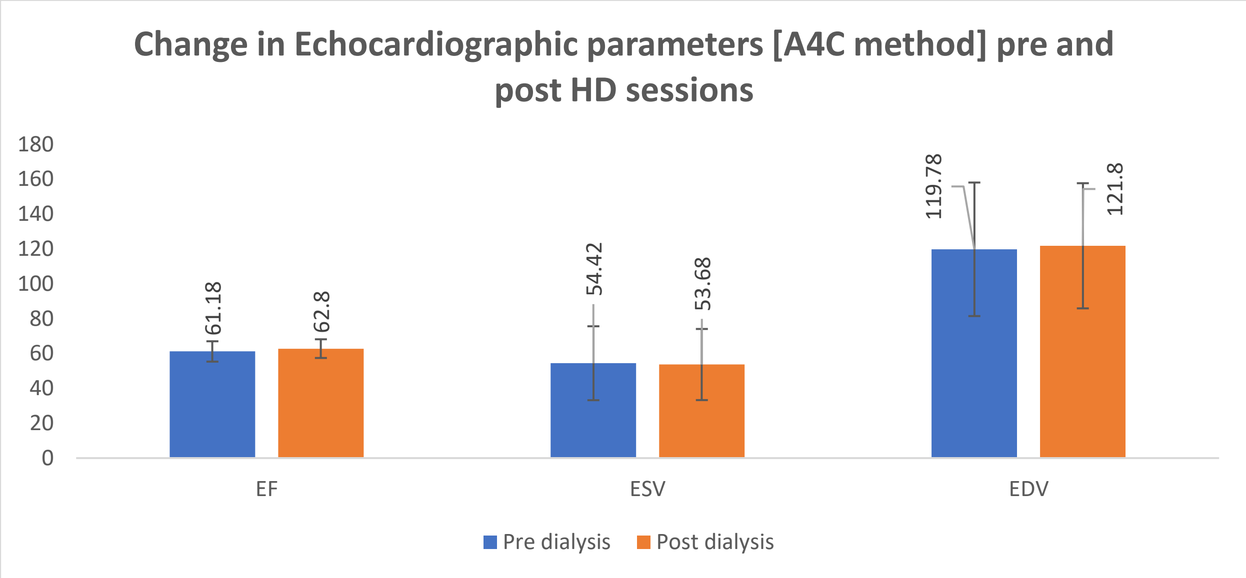

Figure [4]: Difference between pre and post dialysis regarding left ventricular systolic function using A4C echocardiography

Table [7]: Association between pre and post dialysis cardiac parameters assessed by 3D method

3D method	Pre dialysis	Post dialysis	P value*
EF	64 ± 5.75	64.19 ± 5.1	0.562
ESV	58.32 ± 17.32	57.54 ± 16.72	0.865
EDV	140.3 ± 39.08	139.8 ± 39.19	0.550

* Paired sample t test, EF; Ejection fraction. ESV; End systolic volume, EDV; End diastolic volume

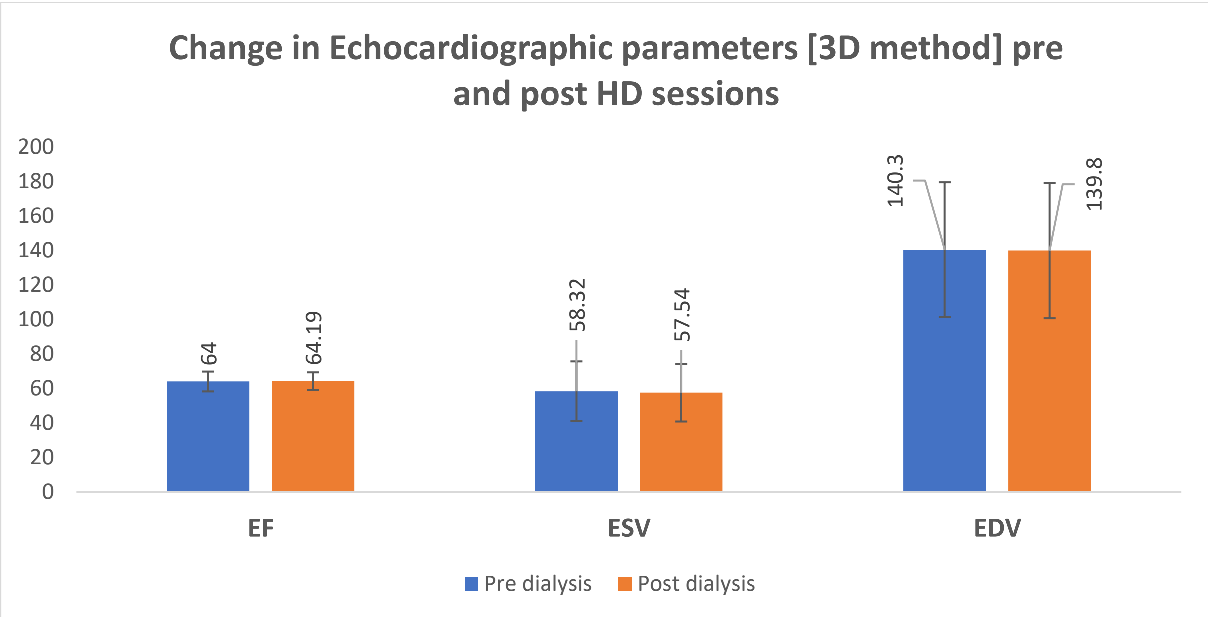

Figure [5]: Difference between pre and post dialysis regarding left ventricular systolic function using 3D echocardiography

Table [8]: Association between pre and post dialysis diastolic dysfunction parameters

Diastolic dysfunction	Pre dialysis	Post dialysis	P value*
E/A ratio	1.69 ± **0.21**	1.59 ± 0.22	0.057
Lateral e	0.11 ± 0.03	0.12 ± 0.02	0.514
Septal e	0.14 ± 0.09	0.15 ± 0.09	0.914
E/e ratio	12.35 ± 0.96	11.94 ± 0.66	0.627

* Paired sample t test, EF; Ejection fraction. ESV; End systolic volume, EDV; End diastolic volume

DISCUSSION

It has been shown that even a little decrease in glomerular filtration rate [GFR] is an independent risk factor for producing cardiovascular problems in patients with chronic kidney disease [CKD]. Those with a glomerular filtration rate [GFR] of 59 mL/min/1.73 m^2 or below had a 38% increased risk of developing cardiovascular disease [CVD] compared to those with a GFR of 90 mL/min/1.73 m^2 [8].

In CKD patients, cardiovascular disease is responsible for more than half of all fatalities. A person with CKD with cardiovascular disease had a mortality risk three to thirty times that of the normal population. In addition, compared to those with normal renal function, those in stages 2 and 3 of chronic kidney disease have a mortality rate that is two- and three-times as high, respectively [8].

That is why monitoring the cardiac condition among hemodialysis patients is crucial. Many modalities were adopted for this purpose. Echocardiography is one of these modalities. It is a useful method in assessment of the cardiac structure and function [5].

While the accuracy of echocardiographic readings is operator dependent, it has been shown to be highly connected with histologic results and has been well verified in epidemiological research over the last several years. As a result, an echocardiographic study may be very useful in determining the efficacy of therapeutic measures, classifying prognostic risk factors, and monitoring the cardiac performance among patients [9].

In our study, we aimed at studying the left ventricular systolic and diastolic functions using echocardiography with different modalities among patients with ESKD undergoing regular hemodialysis. Fifty patients with ESKD undergoing regular hemodialysis were recruited to participate in the study. Echocardiography was made immediately before and after end of dialysis sessions with all modalities.

By using M mode, we found that mean ejection fraction among included patients was 64.46 ± 5.69 % that slightly improved after completion of the dialysis session to be 65.06 ± 5.49 %. regarding the left ventricular dimensions, we found that mean LV ESD was 2.99 ± 0.47 cm with a slight decrease to 2.93 ± 0.49 cm post dialysis. While mean LV EDD was found to be 5.01 ± 0.76 cm with a post dialysis slight reduction into 4.97 ± 0.75 cm.

Our results were consistent with what was reported by **Rakha et al.** [10] who recruited 40 patients with ESKD undergoing regular hemodialysis for more than 3 months in Mansoura university hospitals. In the duration between June 2018 and April 2019. Their mean EF was 63.44 ± 10.59 %. It also did not significantly change after HD session completion [p=0.988]. On the other hand, they reported a significant decrease in left ventricular dimensions whether LVESD that decreased from 2.97 ± 0.71 cm to 2.70 ± 0.62 cm or LVEDD which decreased from 4.65 ± 0.66 cm to 4.11 ± 0.69 cm. This difference may be related to that all included patients in **Rakha et al.** [10] were in the pediatric age group, while mean age of our included patients was 48.92 ± 6.93 years old.

Another study conducted by **Tsilonis et al.** [11] who tested the effect of between dialysis sessions intervals on the cardiac status of patients with ESKD undergoing hemodialysis. That is why they recruited 40 patients divided into 2 groups; 2 sessions and 3 sessions per week regularly. They studied their systolic and diastolic functions pre and post sessions. They reported that no significant change was recorded in EF assessed by m mode among both groups between sessions; [p=0.5, p=0.9] respectively. However, they reported a significant improvement in their left ventricle dimensions; LVEDD decreased from 4.6 ± 1.1 to 4.2 ± 1.1, p=0.005 among patients undergoing 3 sessions per week and from 4.5 ± 1.1 to 4.2 ± 1.1, P<0.001 among patients undergoing 2 sessions per week [11].

As known, 3D echocardiography is more accurate in assessment of cardiac structural and functional abnormalities that occur among patients undergoing hemodialysis as a result of both pressure and volume overload [12].

Kovářová et al. [13] recently conducted a study in which patients with ESKD undergoing hemodialysis in the duration between October 2019 and March 2020 were recruited. They all underwent echocardiographic assessment 24 hours after their last dialysis session to avoid the myocardial stunning and the change of volume status that occur as a result of dialysis sessions. They measured the ejection fraction as an indicator of systolic functions and found that it was 58.05 ± 6.92 among patients undergoing hemodialysis. This was slightly lower than what was reported among patients performed renal transplantation and their age and gender matched healthy controls whom EF was found to be 62.18 ± 4.46% and 59.15 ± 5.9% respectively [13].

We also assessed the systolic function by 3D method and found among their EF was 64 ± 5.75% which did not significantly change after the dialysis session [p=0.562]. In addition, we assessed the left ventricular EDV and found that it was 140.3 ± 39.08 ml. This also did not significantly change after dialysis session [p=0.550]. Our results were slightly more than what was reported by **Kovářová et al.** [13] who reported the LV EDV to be 122.7 ± 30.96 ml. this was slightly higher than those performed renal transplantation who began to recover their renal status that was 110.7 ± 30.11 ml. this may be explained by that volume overload becomes more observed among patients with more renal deterioration degree.

Regarding gender distribution, ESKD is known to be higher among males when compared to females despite that CKD prevalence is high among females. **Ricardo et al.** [14] studied the relationship between gender distribution and CKD progression among nearly 4000 patients with CKD with mean estimated EGFR of 43.9 mL/min per 1.73 mm^2 in females and 45.7 in males. They recorded the incidence of ESKD that require hemodialysis, death and progression to stage 5 in a mean follow up duration of 6.9 years. They reported that despite females had a higher risk for progression of CKD [1.09 mL/min per 1.73 m^2 per year in females and 1.43 mL/min per 1.73 m^2 per year in males], Males were highly susceptible to develop ESKD. This matches what was found in our study in which more than half of included patients were males.

In conclusion, CVD is a common cause for increased morbidities and mortalities among included patients. that is why non-invasive modalities for cardiac monitoring are important. Despite a slight improvement of both cardiac structure and functions. We found no significant change in these parameters immediately after the dialysis sessions. That is why longer follow up period is recommended for future research.

Conflict of Interest and Financial Disclosure: None.

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