

Original Article

Echocardiographic assessment of patients with end-stage renal disease undergoing maintenance hemodialysis

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ABSTRACT

Objectives: Chronic kidney disease is a global health problem. End-stage renal disease (ESRD) patients have a high frequency of cardiac functional and structural abnormalities associated with higher mortality. Echocardiography is a valuable tool to assess cardiac structural and functional changes, which helps in stratifying prognostic risk factors and measuring the effectiveness of therapeutic intervention.

Materials and Methods: We conducted a prospective, cross-sectional, hospital-based study for 1 year from 2076/11/05 to 2077/11/05 B.S (February 17, 2020, to February 17, 2021, A.D. Total of 65 patients with the diagnosis of ESRD undergoing maintenance hemodialysis (MHD) at Chitwan Medical College Hospital meeting inclusion criteria were enrolled. Detailed history, examinations, echocardiographic, and laboratory findings were recorded, and their association was compared with different explanatory variables. Data were analyzed using Statistical Package for the Social Sciences version 25.

Results: The most common echocardiography finding among the 65 patients was valvular heart disease (VHD) (78.50%). Among them, 86.2% were undergoing hemodialysis (HD) twice weekly. About 92.7% had hypertension and 52.3% had diabetes mellitus. All had anemia with a mean hemoglobin of 7.86 ± 1.30 g/dL. The most common echocardiography finding was VHD (78.50%). There were statistically significant associations between the age of patients with a prevalence of VHD and systolic dysfunction; the presence of global hypokinesia with body mass index; and the presence of left ventricular hypertrophy (LVH) with calcium levels. Furthermore, a statistically significant difference in the duration of HD was observed with LVH.

Conclusion: Cardiovascular diseases are the major cause of morbidity and mortality among ESRD patients undergoing MHD. The study identifies various factors influencing echocardiographic parameters in ESRD patients and highlights VHD as the most prevalent echocardiographic finding. It also emphasizes the importance of echocardiography as a valuable tool for assessing cardiac changes in these patients, aiding in risk stratification and the evaluation of therapeutic interventions.

Keywords: Chronic kidney disease, Echocardiography, End-stage renal disease, Hemodialysis, Valvular heart disease

INTRODUCTION

The worldwide estimated prevalence of chronic kidney disease (CKD) is 13.4% (11.7–15.1%) and patients with end-stage renal disease (ESRD) needing renal replacement therapy is estimated between 4.902 and 7.083 million.^[1,2] Cardiovascular disease (CVD) is the major cause of morbidity and mortality in patients with CKD. Coronary artery disease including myocardial infarction, congestive heart failure, and pericardial disease is the common manifestation of

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CKD. Heart failure accounts for 15%, myocardial infarction about 10%, and pericarditis about 3% of dialysis-associated mortality.^[3,4]

MATERIALS AND METHODS

It was a quantitative, prospective, and cross-sectional hospital-based study. The study was conducted in the Department of Internal Medicine (Nephrology), Chitwan Medical College and Teaching Hospital (CMCTH), Bharatpur, Nepal, from 2076/11/05 to 2077/11/05 B.S (February 17, 2020, to February 17, 2021, A.D). Ethical clearance was taken before initiation of the study according to the norms of the Institutional Review Committee (CMC-IRC). Consent was obtained from all the patients enrolled in the study. Inclusion criteria: (1) Age ≥ 18 years and (2) patients with ESRD undergoing maintenance hemodialysis (MHD) for more than 3 months. Exclusion criteria: (1) Patients who were diagnosed with cardiac disease, rheumatic heart disease, myocarditis, and primary heart muscle disease like cardiomyopathies before initiation of hemodialysis (HD); (2) patients who did not give written consent; and (3) patients who were critically ill required intensive care unit care during the study period.

A total of 65 cases fulfilling the inclusion and exclusion criteria were included in the study.

$$\text{Sample Size (N)} = Z^2 p (1-p) / C^2$$

$Z = 1.96$, $Z = \text{constant}$ $C = 10\%$ confidence interval

$P = 20\%$ $P = \text{Prevalence of CVD in patients with renal impairment}$ (In a study of 6,223 people in the Framingham study, 18% of men and 20% of women with renal impairment had CVD).

Detailed clinical history of the patients was collected, and relevant clinical examination of all participants was done by the researcher himself. Confidentiality of the information of the respondents was maintained. Two-dimensional transthoracic echocardiography was done by a qualified cardiologist using the echocardiogram (model: Siemens acusonx 700) in the Department of Cardiology, CMCTH.

- Left ventricular hypertrophy (LVH): The cutoff value of LVH is $>115 \text{ g/m}^2$ for men and $>95 \text{ g/m}^2$ for women.^[5] In cases of HD patients, there are large body-weight variations, which may lead to evaluation errors by body surface indexation. Thus, to calculate left ventricular (LV) mass accurately in HD patients some experts recommended indexing LV mass by height to the 2.7 power.^[6]
- LV systolic dysfunction: LV systolic dysfunction is assessed by measuring ejection fraction (EF) and fractional shortening by echocardiography. EF is calculated by following the formula:

$$EF = (LVEDV - LVESV) / LVEDV$$

where,

- LVEDV=Left Ventricular End Diastolic Volume
- LVESV=Left Ventricular End Systolic Volume

LV EFs of $<52\%$ and $<54\%$ for men and women, respectively, are indicative of abnormal LV systolic function.^[5]

- LV diastolic dysfunction: Diastolic dysfunction is characterized by alterations in ventricular relaxation and compliance. Subsequently, it is frequently followed by a compensatory increase in filling pressure in more advanced stages.^[7]
 - Diastolic function was assessed using several parameters including the pattern of mitral inflow and the ratio of peak early (E) filling velocity to late diastolic filling (A) velocity (E/A ratio), deceleration time of early filling velocity (DT), and the isovolumic relaxation time.^[8]

Normal serum sodium concentration in our body is 135–145 Mm. it is defined as hyponatremia when its concentration is below 135 Mm and more than 145 Mm is leveled as hypernatremia.^[9]

Normal serum potassium concentration in our body is 3.5 mm to 5.5 mm. It is defined as hypokalemia when its concentration is below 3.5 mm and more than 5.5 mm is leveled as hyperkalemia.^[10]

Normal serum calcium is approximately 8.6–10.2 mg/dL below 8.6 mg/dL it is considered hypocalcemia and above 10.2 it is leveled as hypercalcemia.

Body mass index (BMI) = Body weight (kilograms) divided by height squared (meters) According to the World Health Organization (WHO);^[11]

Underweight BMI in the range of 15–19.9 kg/m^2

Normal weight if the BMI is 20–24.9 kg/m^2

Overweight if the BMI is 25–29.9 kg/m^2

Obese if it is 30–35 kg/m^2 or greater.^[11]

The WHO criteria for anemia in men is $<13 \text{ g/dL}$ in men and $<12 \text{ g/dL}$ in women. However, it differs by age, sex, and pregnancy status.^[12]

Data were collected using a self-designed structured pro forma. The collected data were checked, reviewed, and organized for accuracy. The data were entered and analyzed using the Statistical Package for the Social Sciences (IBM SPSS) version 20. Data were summarized using descriptive statistics (frequency, percentage, central tendency, and dispersion). The Chi-square test or Fisher exact test at a 5% level of significance was used to determine the association between variables.

Patients with CKD having CVD had a 3–30 times higher risk of mortality as compared to the general population.^[3] Evaluation of echocardiographic parameters in patients with CKD can provide invaluable information regarding the disease.^[4]

The objectives of the study include echocardiographic assessment among ESRD patients undergoing (MHD); to identify the magnitude of systolic and diastolic dysfunction, LVH, regional wall motion abnormality, pericardial effusion and valvular heart disease (VHD); and the association between the findings with laboratory parameters and some explanatory variables.

RESULTS

A total of 65 patients were enrolled during the study period over 1 year, among which 50% were male and 45.50% were female [Figure 1]. The most common echocardiography finding [Figure 2] in our study was VHD (78.50%), of which the most common VHD [Figure 3] was mitral regurgitation (64.61%) and the least prevalent abnormality was pulmonary regurgitation (1.50%). The prevalence of other findings [Figure 2] in descending order was LV diastolic dysfunction (72.30%), LVH (60%), LV systolic dysfunction (27.70%), pericardial effusion (18.50%), and global hypokinesia (12.30%). The most common frequency of HD [Table 1] was twice a week (86.2%). The most common religion among the patients was Hinduism (95.4%). The mean height was 63.31

inches (standard deviation [SD] 2.474 range 57–72) and the weight was 53.98 kg (SD 10.43 range 30.53–81.72). Overall, 52.3% had a history of diabetes, 92.7% had hypertension, 46.2% had a smoking habit, and 43.1 % had a drinking alcohol habit [Table 1]. The mean hemoglobin was 7.86 ± 1.30 in which the maximum hemoglobin was 10.8 and the minimum was 4.3. It appeared that most of the people had normal serum potassium (53.80%), normal serum Sodium (72.30%), and normal serum calcium (60%); however, there were no cases of hypercalcemia [Figure 4]. The results of bivariate analyses between Echocardiography findings and different independent variables among ESRD patients are shown in [Tables 2 and 3], and the correlation between echocardiography variables with duration in ESRD on HD is shown in [Table 4].

Table 1: History among ESRD patients undergoing maintenance hemodialysis attending CMCTH (n=65).

Variables	Category	Frequency (%)
Diabetes mellitus	Presence	34 (52.3)
	Absence	31 (47.7)
Hypertension	Presence	60 (92.3)
	Absence	5 (7.7)
Smoking habit	Yes	30 (46.2)
	No	35 (53.8)
Alcohol habit	Yes	28 (43.1)
	No	37 (56.9)
Duration of hemodialysis	<1 year	18 (27.6)
	>1 years	47 (72.4)
Frequency of hemodialysis	Once a week	8 (12.3)
	Twice a week	56 (86.2)
	Thrice a week	1 (1.5)

ESRD: End-stage renal disease, CMCTH: Chitwan medical college and teaching hospital

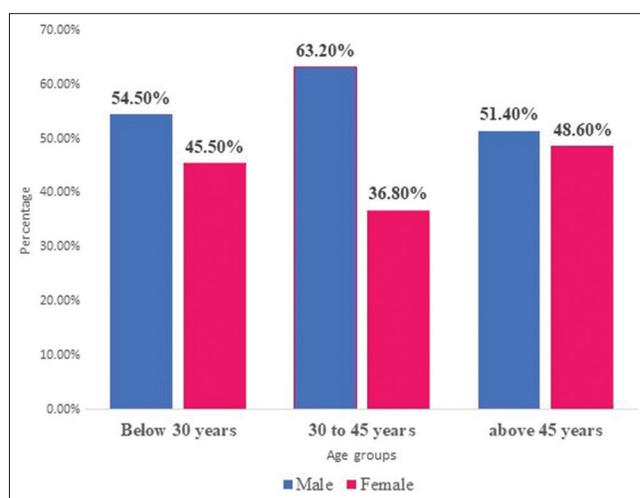


Figure 1: Age-sex distribution among end-stage renal disease patients undergoing maintenance hemodialysis attending Chitwan Medical College and Teaching Hospital.

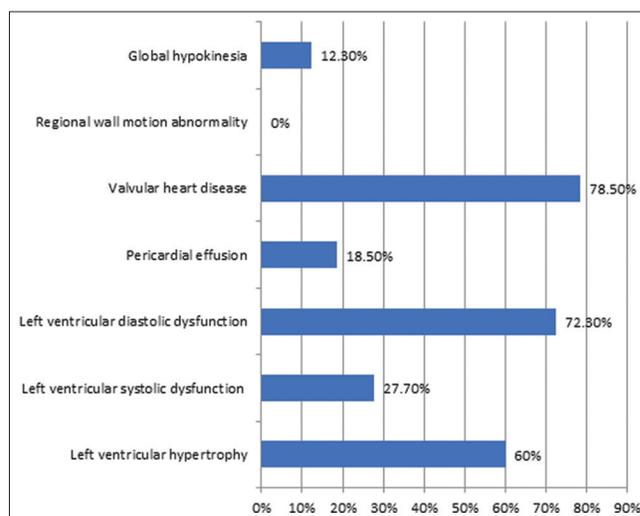


Figure 2: Echocardiographic findings among end-stage renal disease patients undergoing maintenance hemodialysis attending Chitwan Medical College and Teaching Hospital.

Table 2: Bivariate analysis between echocardiographic findings and some independent variables among ESRD patients.

Variables	Valvular heart disease	Global hypokinesia	Pericardial effusion
	Frequency (%)	Frequency (%)	Frequency (%)
Age group			
45 and below	27 (90)	3 (37.5)	6 (20)
Above 45	24 (68.6)	5 (62.5)	6 (17.1)
Sex			
Male	31 (86.1)	6 (75)	7 (19.4)
Female	20 (69)	2 (25)	5 (17.2)
BMI			
Normal	28 (71.8)	3 (37.5)	5 (12.8)
Others	23 (88.5)	5 (62.5)	7 (26.9)
HTN			
Presence	46 (76.7)	8 (100)	11 (18.3)
Absence	5 (100)	0	1 (20)
DM			
Presence	25 (73.5)	4 (50)	6 (17.6)
Absence	26 (83.9)	4 (50)	6 (19.4)
Smoking			
Yes	24 (80)	4 (50)	4 (13.3)
No	27 (77.1)	4 (50)	8 (22.9)
Alcohol			
Yes	23 (82.1)	4 (50)	4 (14.3)
No	28 (75.7)	4 (50)	8 (21.6)
Potassium level			
Normal	29 (82.9)	4 (50)	7 (20)
Hypokalemia/Hyperkalemia	22 (73.3)	4 (50)	5 (16.7)
Sodium level			
Normal	36 (76.6)	5 (62.5)	7 (14.9)
Hyponatremia/Hypernatremia	15 (83.3)	3 (37.5)	5 (27.8)
Calcium Level			
Normal	20 (76.9)	4 (50)	4 (15.4)
Hypocalcemia/Hypercalcemia	31 (79.5)	4 (50)	8 (20.5)

ESRD: End-stage renal disease, BMI: Body mass index, HTN: Hypertension, DM: Diabetes mellitus

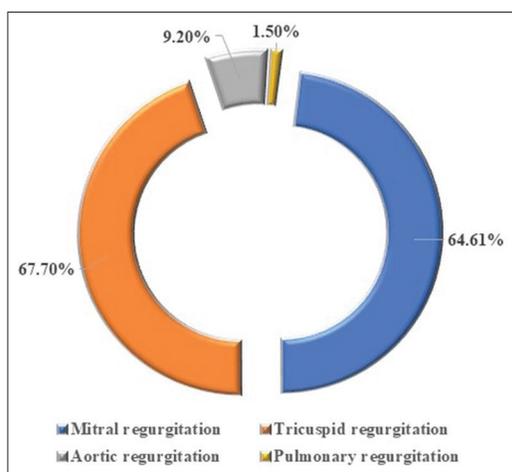


Figure 3: Valvular heart disease among end-stage renal disease patients undergoing maintenance hemodialysis attending Chitwan Medical College and Teaching Hospital.

DISCUSSION

In our study, 50% were males and 45.50% were females, males were predominant which was found to be similar in other studies.^[13,14] The average age of our study population was 47.45 years. This was nearly the same in many other studies.^[15,16] The maximum number of patients undergoing HD in our hospital were from Bharatpur Metropolitan City (35.4%) and Kawasoti (4.1%). The majority of them were Hindu (95.4%) by religion.^[17] These demographic factors may vary based on locality, culture, and religion. Hypertension (92.30%) was by far the most prevalent comorbidity observed in ESRD patients in our study. Hypertension is related to both a cause and effect in CKD patients, controlling hypertension not only slows the progression of renal damage but also reduces the risk of CKD.^[18] A study done in the USA estimated that hypertension occurs in 35.8% of stage 1, 48.1% of stage 2, 59.9% of stage 3, and 84.1% of stage 4–5 CKD patients.^[19]

Table 3: Bivariate analysis between echocardiography findings and some independent variables among ESRD patients.

Variables	Left ventricular hypertrophy	Systolic dysfunction	Diastolic dysfunction
	Frequency (%)	Frequency (%)	Frequency (%)
Age group			
Below 45	17 (56.7)	12 (40)	19 (63.3)
45 above	22 (62.9)	6 (17.1)	28 (80)
Sex			
Male	22 (61.1)	12 (33.3)	25 (69.4)
Female	17 (58.6)	6 (20.7)	22 (75.9)
BMI			
Normal	23 (59)	10 (25.6)	31 (79.5)
Others	16 (61.5)	8 (30.8)	16 (61.5)
HTN			
Presence	36 (60)	17 (28.3)	43 (71.7)
Absence	3 (60)	1 (20)	4 (80)
DM			
Presence	20 (58.8)	10 (29.4)	26 (76.5)
Absence	19 (61.3)	8 (25.8)	21 (67.7)
Smoking			
Yes	20 (66.7)	10 (33.3)	24 (80)
No	19 (54.3)	8 (22.9)	23 (65.7)
Alcohol			
Yes	16 (57.1)	9 (32.1)	21 (75)
No	23 (62.2)	9 (24.3)	26 (70.3)
Potassium level			
Normal	21 (60)	9 (25.7)	26 (74.3)
Hypokalemia/hyperkalemia	18 (60)	9 (30)	21 (70)
Sodium level			
Normal	31 (66)	14 (29.8)	37 (78.7)
Hyponatremia/hyponatremia	8 (44)	4 (22.2)	10 (55.6)
Calcium			
Normal	12 (46.2)	8 (30.8)	15 (57.7)
Hypocalcemia/hypercalcemia	27 (69.2)	10 (25.6)	32 (82.1)

ESRD: End-stage renal disease, BMI: Body mass index, HTN: Hypertension, DM: Diabetes mellitus

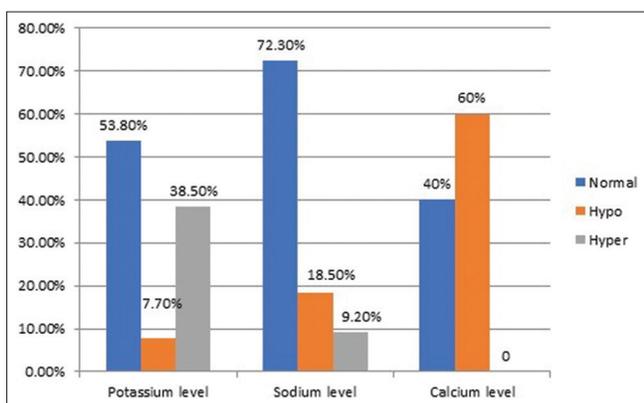


Figure 4: Distribution of potassium, sodium, and calcium levels among end-stage renal disease patients undergoing maintenance hemodialysis attending Chitwan Medical College and Teaching Hospital.

The majority of patients in our study were undergoing HD twice a week (86.2%), followed by thrice a week (1.5%) and

once a week (12.3%) for 4 h per session. The mean hemoglobin level in our study was 7.86 ± 1.30 g/dL and 100% had anemia (hemoglobin [Hb] <11 g/dL). A study by Adera *et al.* shows that the prevalence of anemia increased with worsening kidney function: stage 1 and 2, 3A, 3B, 4, and 5 CKD were 20%, 44.8%, 46.4%, 81.1%, and 93.8%, respectively. Severe anemia (Hb <8 g/dL) was documented in 49/251 (19.5%) of CKD patients.^[20] The average level of serum calcium and serum phosphorus was 7.91 mg/dL, and 4.97 ± 1.34 mg/dL, respectively, in our study. The mean level of Hb, serum calcium, serum phosphorus, and serum albumin observed in the study by Hamin *et al.* was 10.98 ± 1.4 g/dL, 281.5 pg/mL, 0.75 ± 1.34 mg/dL, and 3.66 ± 0.39 g/dL, respectively.^[21]

The most common echocardiography finding in our study was VHD which was seen in 51 patients (78.52%). The other findings in descending order were LV diastolic dysfunction (LVDD) (72.30%), LVH (60%), LV systolic dysfunction (27.70%), pericardial effusion (18.5%), Global hypokinesia (12.3%), and regional wall motion abnormalities nil. The

Table 4: Correlation between echocardiography variables with duration in ESRD on hemodialysis.

Echocardiographic findings	Duration	
	≤12 months	>12 months
Left ventricular hypertrophy		
Yes	1	39
No	17	8
Left ventricular diastolic dysfunction		
Yes	4	43
No	4	14
Valvular heart disease		
Yes	7	44
No	1	13
Left ventricular systolic dysfunction		
Yes	0	18
No	8	39
Mitral regurgitation		
Yes	1	41
No	17	6
Pericardial effusion		
Yes	3	9
No	5	48
Global Hypokinesia		
Yes	0	8
No	8	44

ESRD: End stage renal disease

major echocardiographic changes observed by Saxena *et al.* was VHD: tricuspid regurgitation (TR) in 33(66%) mitral regurgitation (MR) in 24 (48%) patients LVH in 29 (58%) patients, LVDD in 25 (50%) patients, pericardial effusion in 10 (20%) patients, pulmonary hypertension in 23 (46%) patients, dilated left atrium in 14 (28%) patients, dilated left ventricle in 4 (8%) patients, and regional wall motion abnormalities in 3 (6%) patients also there was no cases of valvular calcification.^[22] There was a statistically significant association between age group and prevalence of VHD in our study which was similar to different another study. Data from the US Renal Data System in 2017 showed that the prevalence of VHD diagnoses was 14% among patients with CKD compared with 7% in the medicare survey of patients aged >65.^[23] Furthermore, the presence of LVH was found to be significantly associated with the serum calcium level. A study by Nitta *et al.* also shows a significant association with hypocalcemia although the mechanism is not completely known, hypocalcemia followed by Vitamin D deficiency may be associated with the pathogenesis of LVH.^[24]

The presence of global hypokinesia was also found to be statistically significant with the BMI. In our study 39 patients had normal BMI, eight patients had overweight, and 18 patients were underweight. Malnutrition increases the risk of morbidity and mortality among ESRD patients undergoing HD. Being overweight is one of the risk factors

for hypertension and diabetes mellitus which are the most common etiological factors of ESRD. The presence of systolic dysfunction was found to be statistically significant with the age of the patient in our study which was not found to be significant in other similar studies.

The duration of HD also plays an important role in cardiovascular outcomes.^[25] In our study, HD duration was categorized into ≤12 months and >12 months. Thirty-nine patients who were doing HD for >12 months developed LVH compared to 1 patient in the ≤12 months group. Our study showed a significant correlation between longer duration of HD and LVH ($P < 0.0001$). In the study by Kaze *et al.* also observed a significant positive relation between longer duration of HD and LVH ($P < 0.047$).^[26] LVH is reported in 16–50% of early and intermediate CKD (Stages 1–3) patients, 50–70% of advanced CKD (Stages 4 and 5) patients, and in up to 70–90% of regular dialysis patients.^[27]

Another echocardiography parameter that was found to be statistically correlated with the duration of HD in our study was MR ($P < 0.0001$). These results were in contrast to many other studies.^[28]

CONCLUSION

The study holds significant clinical importance as it addresses the escalating global issue of CKD. HD remains the predominant renal replacement therapy for sustaining patients. CVDs contribute significantly to morbidity and mortality in ESRD patients undergoing HD. The study identifies various factors influencing echocardiographic parameters in these patients and highlights VHD as a prevalent echocardiographic finding. Significantly, echocardiography emerges as the simplest yet most reliable method for evaluating cardiac function in ESRD patients on HD. This emphasizes the crucial role of echocardiography in detecting cardiac abnormalities, thus aiding in risk assessment and guiding appropriate interventions for these patients.

Authors contributions

Roshan Bhandari: Concept, design, literature search, manuscript preparation, statistical analysis and editing, data analysis. Srijan Panth: Concept, design, literature search, manuscript preparation, data acquisition and analysis. Ghanashyam Pandey: Concept, design, literature search, manuscript preparation, statistical analysis and editing. Richa Paudyal: Concept, design, literature search, manuscript preparation, statistical analysis and editing. Guarantors: Roshan Bhandari, Srijan Pantha.

Declaration of patient consent

Institutional Review Board (IRB) permission was obtained for the study.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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