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Chronic kidney disease and right ventricular dysfunction; an echocardiographic assessment in hemodialysis patients

Kannika Logu[1,2], Karthikeyan Balakrishnan[1], Melina Sahay[3], Melvin George[3], Sriram Damal Kandadai[3], Dhandapani Vellala Elumalai[2], Vengatesh Munisamy[2], Saravanan Ayyavoo[4*]

[1]Department of Cardiology, Hindu Mission Hospital, Chennai, Tamilnadu, India
[2]Department of Cardiology, SRM Medical College Hospital and Research Centre, Kattankulathur, Chengalpattu, Tamilnadu, India
[3]Department of Clinical Research, Hindu Mission Hospital, Chennai, Tamilnadu, India
[4]Department of Physiology, SRM Medical College Hospital and Research Centre, Kattankulathur, Chengalpattu, Tamil Nadu, India

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ABSTRACT

Introduction: Cardiovascular complications are the primary cause of mortality in individuals with advanced kidney disease, with heart failure being the most prevalent condition. Right ventricular (RV) dysfunction plays a critical role in increasing morbidity and mortality rates in patients with chronic renal disease.
Objectives: The study aimed to investigate the occurrence of RV dysfunction in patients receiving hemodialysis.
Patients and Methods: Observational study was assessed 129 hemodialysis patients with end-stage renal disease at the department of cardiology and nephrology. Screening was conducted based on their estimated glomerular filtration rate (eGFR) levels, and data were gathered on their medical history, demographics, dialysis records, and cardiac risk factors. Two-dimensional and M-mode echocardiography were conducted to evaluate echocardiographic parameters, including tricuspid annular plane systolic excursion (TAPSE), systolic pulmonary artery pressure (SPAP), inferior vena cava (IVC), and right ventricle (RV) thickness.
Results: This study examined how heart function relates to various factors in patients with diabetes and hypertension. The findings suggested a potential association between age and heart function, while no significant connections were observed with gender or kidney function. Additionally, thicker RV walls were associated with enhanced systolic function, and both TAPSE and SPAP exhibited weak correlations with IVC diameter.
Conclusion: Chronic kidney disease (CKD) can result in early-onset RV failure and pulmonary hypertension. Further research is needed to confirm the effectiveness of echocardiography in detecting RV failure in hemodialysis patients. Early identification of RV dysfunction and pulmonary hypertension in individuals with CKD can significantly improve their prognosis and treatment outcomes.

Implication for health policy/practice/research/medical education:
As chronic kidney disease (CKD) becomes more severe, right ventricular (RV) dysfunction and pulmonary hypertension develop earlier and worsen. Therefore, using echocardiography, a non-invasive and affordable method, to test tricuspid annular plane systolic excursion (TAPSE) and systolic pulmonary artery pressure (SPAP) for pulmonary hypertension and identify RV dysfunction early on could improve the prognosis and treatment of these patients.

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Introduction

Chronic kidney disease (CKD) is characterized by a long-term and progressive decline in both the structural integrity and functional capacity of the kidneys, lasting over three months (1). Globally, the prevalence of end-stage renal disease ranges from 7% to 12%, with a rising trend, particularly in developing countries. Cardiovascular disease is the primary cause of death among individuals with end-stage kidney failure, creating significant challenges for prognosis and treatment (2). Patients with

***Corresponding author**: Saravanan Ayyavoo, Email: cardiacresearch@13gmail.com, hod.physiology.ktr@srmist.edu.in

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CKD undergoing hemodialysis are especially vulnerable to cardiovascular-related mortality, which constitutes 40% of deaths according to international registries. The individuals with this condition also face an elevated risk of pulmonary hypertension due to factors such as endothelial dysfunction, vascular calcification, arterial stiffness, volume overload, arteriovenous fistulae, sleep disorders, dialysis membrane exposure, and severe anemia (3). The progression of right ventricular (RV) volume overload can trigger a harmful cycle, exacerbating RV (*right ventricle*) remodeling through various mechanisms (4). When left ventricular (LV) function diminishes and heart failure persists, adverse effects become particularly evident, especially if the tricuspid annular plane systolic excursion (TAPSE) is less than 14 mm. It is crucial to maintain adequate venous return and ensure sufficient cardiac output to manage the complex interaction between RV dysfunction and CKD (5). Chronic RV overload impairs LV filling and function, causing the interventricular septum to paradoxically shift towards the left. This results in the RV taking on a D-shaped appearance, a sign of RV dysfunction or right heart failure. Severe RV dysfunction, indicated by a TAPSE < 14 mm, is associated with significant renal impairment and worsens with severe tricuspid regurgitation (6). This study investigates the impact of CKD on RV function and structure, focusing on patients with RV dilation, elevated pulmonary artery pressure, tricuspid annular dilation, and tricuspid regurgitation, as analyzed through 2D echocardiography. Although most clinical studies have focused on LV function, a significant gap exists in understanding how dialysis therapy affects RV dysfunction. Research specifically linking hemodialysis to RV dysfunction is limited compared to studies on other cardiovascular conditions in end-stage renal disease patients. The unique geometry and function of the RV make precise measurement challenging, which has led researchers to prioritize the left ventricle due to its crucial role in systemic circulation and its association with adverse outcomes (7). Addressing this gap is crucial for improving the management and outcomes of CKD patients undergoing dialysis therapy. Therefore, our study aims to fill this gap by investigating whether RV dysfunction is more prevalent among CKD stage 5 hemodialysis patients. Using echocardiographic evidence, we seek to facilitate early detection and enhance the prediction of patient outcomes. Further research with advanced imaging techniques and larger sample sizes is essential to achieve a comprehensive understanding of the impact of dialysis therapy on RV function (8).

Objectives

Our study aims to fill this gap by examining whether there is an increase in RV dysfunction among CKD stage 5 hemodialysis patients, leveraging evidence from echocardiography to facilitate early detection and improve the prediction of patient outcomes.

Patients and Methods

Study design

This observational study was conducted in the nephrology and cardiology departments from March 2023 to November 2023, involving 129 patients undergoing hemodialysis. Patients were evaluated using the CKD-EPI formula (9) with exclusion criteria including known coronary artery disease, significant valvular disease, LV systolic dysfunction (LV ejection fraction <50%), congenital heart disease, atrial fibrillation, and chronic pulmonary disease. Each patient underwent a comprehensive physical examination, which recorded their age, gender, presence of diabetes mellitus, and hypertension. Clinical assessments included pulse evaluation, blood pressure measurements (systolic and diastolic), and laboratory tests. Echocardiographic evaluations were performed using the DC-60 Mindray echocardiography device in the department of cardiology. Both two-dimensional and M-mode echocardiography were conducted. TAPSE was measured by positioning a M-mode cursor across the tricuspid annulus and evaluating its longitudinal motion at peak systole using a standard apical four-chamber view. Pulmonary artery systolic pressure (PASP) was measured, and RV systolic pressure (RVSP) was calculated using the simplified Bernoulli equation. RVSP was then combined with an estimate of right atrial pressure (RA pressure), calculated based on inferior vena cava (IVC) diameter and its respiratory variations, to provide a comprehensive assessment of RVSP (10).

Statistical analysis

The data were analyzed using SPSS version 16.0 software. Categorical data were analyzed to determine proportions. The chi-square statistic was conducted to assess statistically significant differences between two groups' proportions. For continuous data, means and standard deviations were calculated. A *P* value of ≤0.05 was considered statistically significant in all two-tailed analysis.

Results

Table 1 summarizes the baseline characteristics of our study participants. Most participants were men, and many had pre-existing health conditions such as diabetes and high blood pressure. Laboratory tests showed elevated levels of kidney waste products and abnormal electrolyte levels.

Table 2 illustrates the age distribution of patients categorized by two heart conditions; RV dysfunction (TAPSE) and pulmonary hypertension (SPAP). Among patients with TAPSE measurements below 16 mm, the highest frequency is observed in the 60–69-year age group (36.2%). Conversely, patients with TAPSE measurements above 16 mm are most frequently found in the 30-39-year age group (17.1%). For SPAP measurements, patients with values below 35 mm are predominantly in the 30-39-year age group (19.3%) and the 60-69-year age group (21.1%).

Table 1. Baseline assessment of cardiovascular health in patients undergoing dialysis

Parameters	Mean ± SD
Age	56 ± 15
Gender	
Male	92 (71.3)
Female	37 (28.7)
Diabetic mellitus	73 (56.6)
Hypertension	104 (80.6)
Duration of dialysis	
≤6 months	64 (49.6)
1 year	27 (20.9)
2–3 years	7 (5.4)
4–5 years	16 (12.4)
> 5 years	15 (11.6)
Vital signs	
Systolic blood pressure (mm Hg)	137.74 ± 28.42
Diastolic blood pressure (mm Hg)	80.54 ± 12.26
Heart rate bpm	83.99 ± 15.88
body mass index (kg/m²)	24.61 ± 4.34
hemoglobin (%)	9.25 ± 2.10
Laboratory values	
Urea (mmol/L)	125.77 ± 81
Creatinine (mg/dl)	8.34 ± 4.7
Sodium (mEq/L)	135.02 ± 8.3
Potassium (mEq/L)	4.86 ± 1.001
eGFR (mL/min/m²)	7.99 ± 5.27
Echocardiographic parameters	
TAPSE (mm)	15.25 ± 5.62
SPAP (mm Hg)	38.72 ± 9.20
RV thickness (cm)	0.94 ± 0.29
IVC (cm)	1.69 ± 0.41

eGFR: Estimated glomerular filtration rate; TAPSE: Tricuspid annular plane systolic excursion; SPAP: Systolic pulmonary artery pressure; RV: Right ventricular; IVC: Inferior vena cava.

Table 2. Age distribution for patients with and without RV dysfunction (TAPSE) and pulmonary hypertension (SPAP)

		TAPSE (mm)		SPAP (mm)	
		<16	>16	<35	>35
Age distribution (y)	<30	1 (2.1)	3 (3.7)	2 (3.5)	2 (2.8)
	30–39	3 (6.4)	14 (17.1)	11 (19.3)	6 (8.3)
	40–49	8 (17)	11 (13.4)	9 (15.8)	10 (13.9)
	50–59	9 (19.1)	16 (19.5)	12 (21.1)	13 (18.1)
	60–69	17 (36.2)	22 (26.8)	12 (21.1)	27 (37.5)
	70–79	8 (17)	12 (14.6)	10 (17.5)	10 (13.8)
	80–89	1 (2.1)	4 (4.9)	1 (1.8)	4 (5.6)

Table 3. The gender distribution for patients with and without RV dysfunction (TAPSE) and pulmonary hypertension (SPAP)

		TAPSE (mm)		SPAP (mm)	
		<16	>16	<35	>35
Gender	Male	31 (33.7)	61 (66.3)	41 (44.6)	51 (55.4)
	Female	16 (43.2)	21 (56.9)	16 (43.2)	21 (56.8)

Table 4. The distribution of diabetics and hypertensive patients by RV dysfunction (TAPSE) and pulmonary hypertension (SPAP)

		TAPSE (mm)		SPAP (mm)	
		<16	>16	<35	>35
Diabetics and HTN	DM	31 (42.5)	42 (57.5)	31 (54.4)	42 (58.3)
	HTN	36 (34.6)	68 (65.4)	44 (77.2)	60 (83.3)

HTN: Hypertension; DM: Diabetics mellitus.

Conversely, those with SPAP measurements above 35 mm are more frequently in the 60–69-year age group (37.5%). These findings suggest potential age-related associations with RV dysfunction and pulmonary hypertension, with distinct distributions observed across different age groups and TAPSE/SPAP measurements.

Table 3 reveals no statistically significant difference in the overall prevalence of RV dysfunction or pulmonary hypertension between genders. There is a slight increase in the percentage of females (43.2%) compared to males (33.7%) among patients with TAPSE measurements below 16 mm, which may indicate possible RV dysfunction. Gender distribution across other categories remains relatively similar.

Table 4 shows that the proportion of diabetics and hypertensive cases with potential RV dysfunction (TAPSE < 16 mm) is comparable to those with normal RV function (TAPSE ≥ 16 mm). However, there is a higher prevalence of pulmonary hypertension (SPAP ≥ 35 mm) among both diabetics and hypertensive individuals compared to those with normal pulmonary pressure (SPAP < 35 mm).

Table 5 reveals no statistically significant correlations between estimated glomerular filtration rate (eGFR) and other parameters, suggesting that kidney function (eGFR) may not be strongly related to heart function or blood pressure measures in this patient group. However, a weak positive correlation was observed between TAPSE and RV thickness (0.314), indicating that thicker RV walls are associated with slightly better systolic function. TAPSE did not show significant correlations with SPAP or IVC. Interestingly, a moderate positive correlation was found between TAPSE and IVC diameter (0.314), suggesting that thicker RVs might be linked to some degree of impaired blood flow returning to the heart, as reflected by a wider IVC. Additionally, a weak positive correlation was noted between IVC diameter and SPAP (0.072), hinting that higher pulmonary artery pressure (SPAP) might be marginally associated with increased IVC diameter.

Table 5. Correlation coefficients between kidney function, right ventricle function, and blood pressure measures in dialysis patients

		eGFR	TAPSE	RV thick	IVC	SPAP
eGFR	Pearson's correlation	1	0.022	0.086	0-.070	0-0.092
	Sig. (2-tailed)		0.804	0.335	0.432	0.301
	N	129	129	129	129	129
TAPSE	Pearson's correlation	0.022	1	0-0.058	0.080	0.038
	Sig. (2-tailed)	0804		0.517	0.368	0.665
	N	129	129	129	129	129
RV thick	Pearson's correlation	0.086	0-.058	1	0.314**	0.001
	Sig. (2-tailed)	0.0335	0.517		0.000	0.991
	N	129	129	129	129	129
IVC	Pearson's correlation	0-0.070	0.080	0.314**	1	0.072
	Sig. (2-tailed)	0.432	0.368	0.000		0.420
	N	129	129	129	129	129
SPAP	Pearson's correlation	0-0.092	0.038	0.001	0.072	1
	Sig. (2-tailed)	0.301	0.665	0.991	0.420	
	N	129	129	129	129	129

eGFR: Estimated glomerular filtration rate; TAPSE: Tricuspid annular plane systolic excursion; SPAP: Systolic pulmonary artery pressure; RV: Right ventricular; IVC: Inferior vena cava.

** Correlation is significant at the 0.01 level (2-tailed).

Discussion

Recent research has explored the incidence of pulmonary hypertension and RV dysfunction in CKD, with RV dysfunction often emerging in the early stages of CKD. While many studies have focused on the prevalence and management of pulmonary hypertension in end-stage renal disease patients (11), RV dysfunction is particularly significant, especially in those undergoing hemodialysis (12). For instance, research published in the American Journal of Kidney Diseases in 2011 found that around 16% of individuals with stage 3–4 CKD exhibited pulmonary hypertension, with its occurrence increasing as kidney function declined.

Understanding the factors contributing to RV dysfunction in CKD patients is crucial for improving management and outcomes (13). This study investigated the relationships among key factors such as RV thickness, IVC characteristics, eGFR, and TAPSE. Our goal was to understand how these variables interact and their impact on RV function in CKD patients, particularly those undergoing hemodialysis. Our findings provide valuable insights into the connections between TAPSE, eGFR, IVC characteristics, and RV thickness, revealing novel information about their relationships. Notably, we identified associations among TAPSE, eGFR, and IVC values, suggesting these measures could serve as potential markers for RV dysfunction in CKD patients. Recognizing these relationships has significant therapeutic implications, indicating that monitoring TAPSE, eGFR, and IVC characteristics could facilitate early detection of RV dysfunction. This would allow for timely interventions to improve both cardiac and renal health. Incorporating these measures into routine clinical practice could enhance patient outcomes and offer more effective management for individuals with CKD.

As per the guidelines of the American Society of Echocardiography, a TAPSE value below 16 mm is indicative of RV dysfunction. Therefore, in our study, we used a TAPSE value below 16 mm as a marker of RV dysfunction (14). In the study by Floccari et al, 44.5% of the 202 patients exhibited mild TAPSE reduction (less than 18 mm), while 10.3% had moderate reduction (less than 15 mm). Although Floccari et al found no correlation between TAPSE and GFR, similar to our findings, the study by Dini et al identified a significant linear correlation between TAPSE and GFR (14,15).

In the study by López-Candales et al, TAPSE, which assesses the longitudinal function of the RV, was found to decrease with both right and LV dysfunction, with a more pronounced reduction in patients with RV dysfunction (16). However, in our study, TAPSE showed no significant change in patients undergoing hemodialysis. This lack of significant change might be attributed to the deterioration of RV function due to increased volume load. Harp et al highlighted that age is a significant factor for the development of pulmonary hypertension in dialysis patients, noting a higher incidence in older age groups.

Conversely, studies Patel et al failed to observe a significant link between age and the occurrence of pulmonary hypertension (11,17). In our study population, 36% were aged 60-69 years, with fewer than 19% in the 50-59-year age group. These findings have important clinical implications, as monitoring IVC parameters may enable early detection of RV dysfunction, allowing for timely treatment adjustments to manage volume status and reduce venous congestion, and 17% in both the 70-79 year and 40-49-year age groups, all exhibiting TAPSE and SPAP values below 16 mm. Meanwhile, Nagaraj et al found that in hemodialysis patients with pulmonary hypertension, the average age was 56.5 ± 9.3 years, with the majority being male. Their study did not reveal a significant association between age or gender and the prevalence of pulmonary hypertension (18,19). Similarly, Tarras et al also reported no significant effect of gender on the prevalence of pulmonary hypertension (20,21).

According to the study by a Cicala et al, individuals with hypertension did not show changes in TAPSE, a key measure of RV systolic performance (22). Inas et al observed statistically significant differences in pulsed-wave tissue Doppler parameters such as S wave, E' wave, and E/E' among individuals with hypertension, diabetes, both conditions, and neither condition (22,23). Karaye et al identified that RV diastolic dysfunction could act as an early indicator of right ventricular dysfunction in individuals with hypertension (24). Pedrinelli et al studied the influence of hypertension on the RV in non-obese, untreated patients, finding decreases in both systolic and diastolic functions even with modest increases in blood pressure (25). Tsilonis et al reported a s notable enlargement in IVC diameter, right atrial volume, and RVSP over a 3-day period, despite stable LV systolic function. This suggests that RV failure is a primary driver of adverse outcomes, aligning with findings from our study (26).

Our study identified significant correlations between RV thickness and IVC characteristics, suggesting that IVC measurements could be useful in predicting RV dysfunction in hemodialysis patients. Integration has important clinical implications, as monitoring IVC parameters may enable early detection of RV dysfunction, allowing for timely treatment and limitation to manage volume status and reduce venous congestion. Integrating IVC assessments into routine clinical practice could improve management strategies and patient outcomes for individuals undergoing hemodialysis.

Conclusion

Early-onset RV failure and pulmonary hypertension are critical complications in CKD, potentially leading to higher morbidity and mortality rates. Although our study did not reveal significant differences among the groups, we advocate for multicenter analytical studies to further assess the effectiveness of echocardiography in detecting RV failure in hemodialysis patients. Additional research is essential to advance the early identification of RV dysfunction and pulmonary hypertension in CKD patients. Enhancing the use of these diagnostic tools could significantly improve prognosis and treatment outcomes for this vulnerable population.

Limitations of the study

Our study has some inherent limitations. The relatively small number of participants recruited from a single center restricts how broadly our findings can be applied to other populations. Furthermore, the lack of catheterization of the right heart, the definitive diagnostic tool for pulmonary hypertension, prevents a conclusive determination of its presence or absence in our study group.

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Author's contribution

Conceptualization: Karthikeyan Balakrishnan, Saravanan Ayyavoo, Kannika Logu.
Data curation: Kannika Logu.
Formal analysis: Kannika Logu, Dhandapani Vellala Elumalai.
Investigation: Kannika Logu, Karthikeyan Balakrishnan.
Methodology: Kannika Logu, Vengatesh Munisamy.
Project administration: Kannika Logu, Saravanan Ayyavoo, Karthikeyan Balakrishnan.
Resources: Saravanan Ayyavoo.
Software: Melina Sahay, Melvin George.
Supervision: Karthikeyan Balakrishnan, Saravanan Ayyavoo, Melvin George.
Validation: Dhandapani Vellala Elumalai.
Visualization: Sriram Damal Kandadai, Karthikaeyan Balakrishnan.
Writing–original draft: Kannika Logu, Melina Sahay.
Writing–review & editing: Kannika Logu, Melina Sahay, Melvin George.

Ethical issues

The research conducted in this study adhered to the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to any intervention. This study approved by Institutional Ethics Committee Hindu Mission Hospital, Tambaram (IEC APPROVAL#HMH/IEC/2022/STEA22). The authors have fully complied with ethical issues, such as plagiarism, data fabrication, and double publication.

Conflicts of interest

The authors declare that they have no competing interests.

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